Vulnerable Californians Experience Greater Pollutant Exposure and Impact

Ying-Ying Meng, DrPH
Co-Director of the Chronic Disease Program
UCLA Center for Health Policy Research

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Background

- Asthma is one of the most common chronic conditions in the United States.
  - 4.5 million Californians suffer from asthma (CHIS 2003).[1]
  - Another 3.4 million Californians suffer from asthma-like symptoms (CHIS 2003).[1]

- **Some populations suffer disproportionately from asthma:**
  - Children
  - The elderly[2]
  - Racial/ethnic minorities[3]
  - Those with low-income[2]

- For example, low income and racial/ethnic minority sub-populations have more urgent care visits[4] and frequent asthma symptoms.[3]

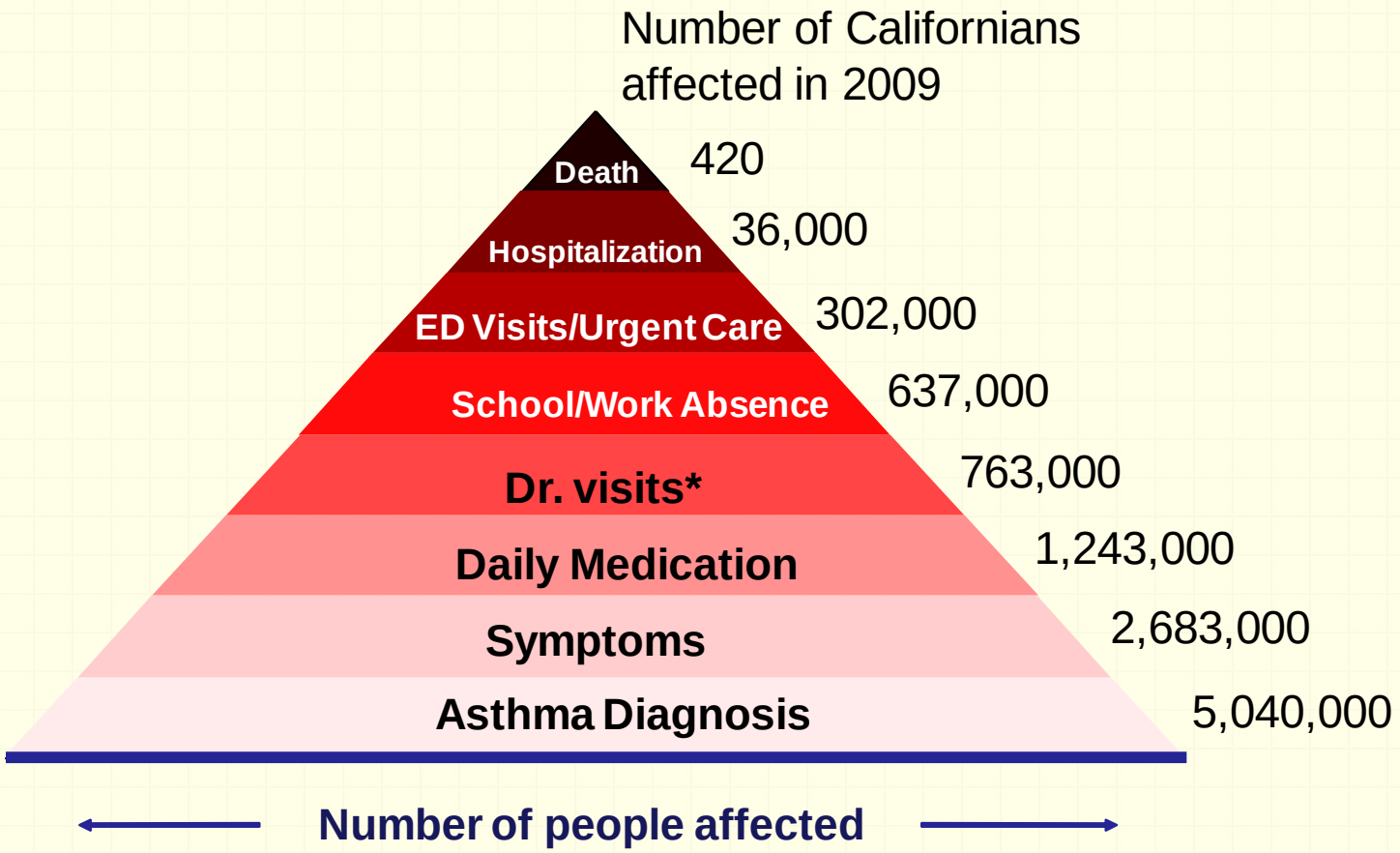
Background

- Air pollutant exposure has been associated with reduced lung function, respiratory inflammation, lung congestion, asthma attacks, emergency department (ED)/hospital visits, medication use, and absences from school.

- **The same sub-populations who suffer more from asthma are more affected by pollutants due to higher exposures or increased susceptibility.**
  - Children[5]
  - Low income individuals[6,7]
  - Racial/ethnic minorities[8-11]

Pyramid of Asthma Burden in California

(Adapted from the American Thoracic Society)



* 9 or more Dr. visits, not necessarily asthma-related

Data Sources: State of California, Department of Public Health, Death Records; Office of Statewide Health Planning and Development, CHIS 2009

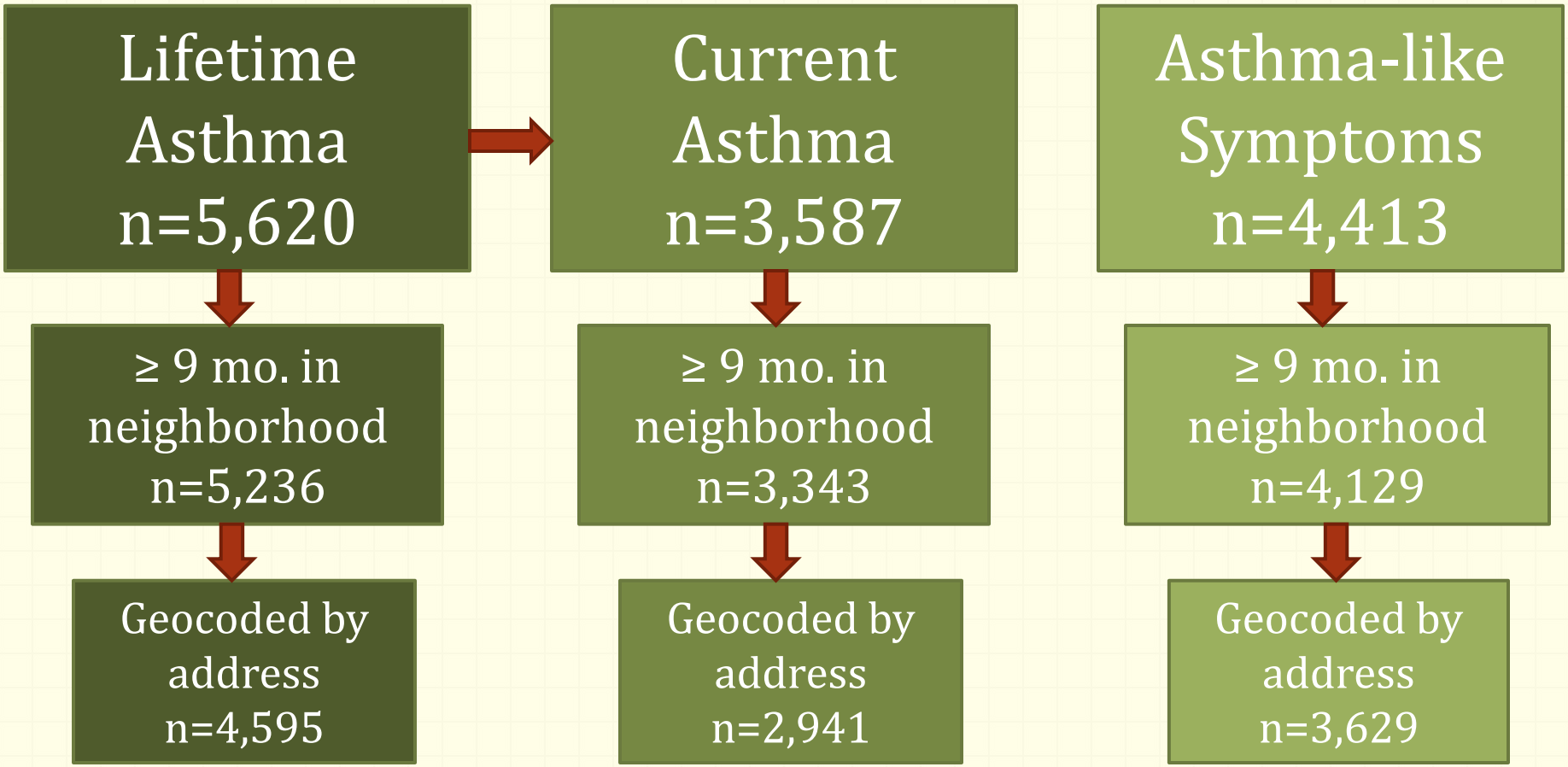
California Health Interview Survey (CHIS)

- A two-stage, geographically stratified random-digit-dial (RDD) telephone survey conducted biannually since 2001 in California
- Interviews conducted in five different languages
- Information collected on more than 54,500 non-institutionalized Californians in each survey, with many standard health questions, including asthma-related questions from the National Health Interview Survey
- Geocodable residential address information, as well as information on duration of residence in the same neighborhood

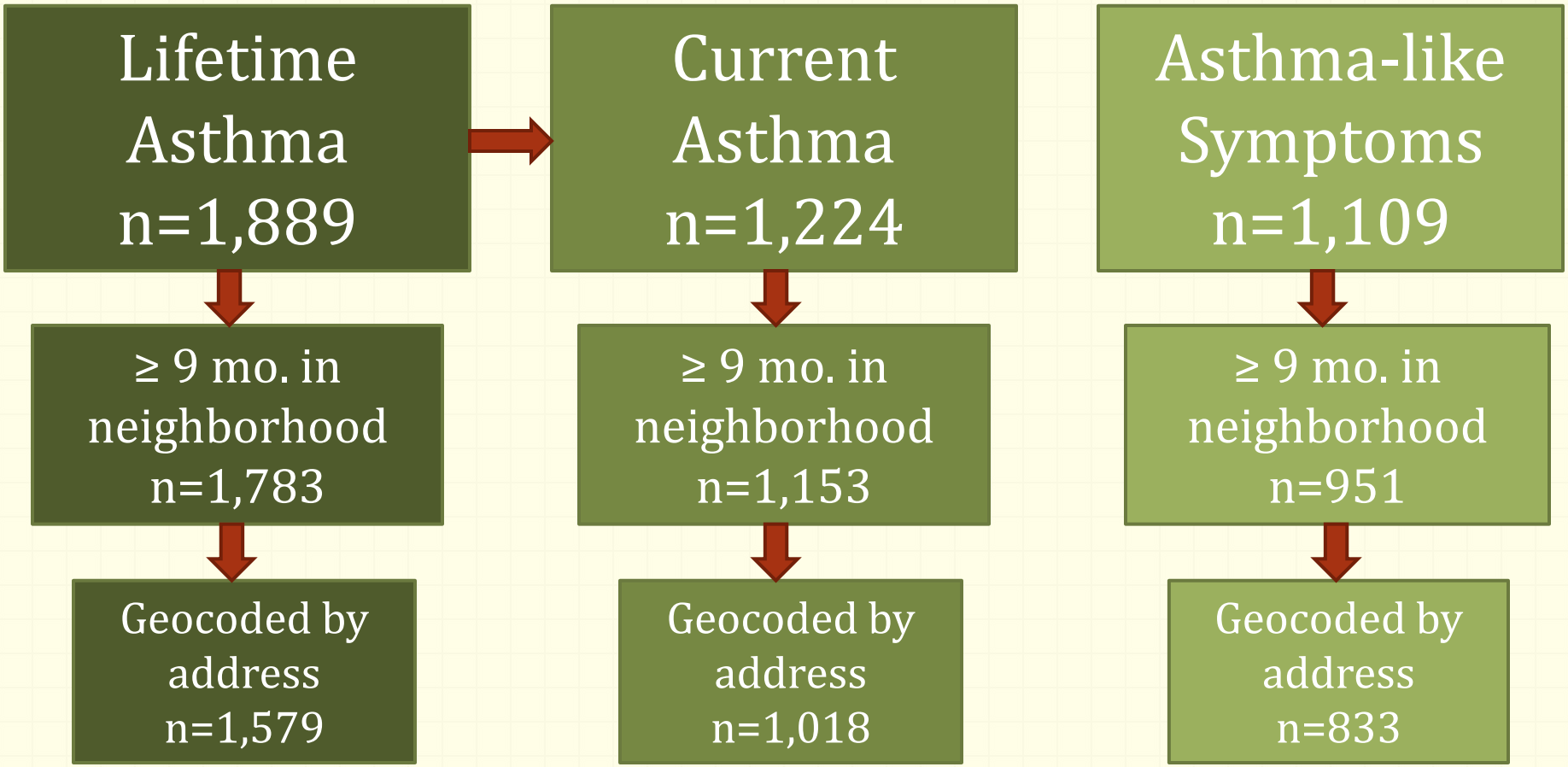
Study Population Definitions

- Lifetime Asthma: those ever diagnosed with asthma
- Current Asthma: those with lifetime asthma who reported still having asthma and/or having an asthma attack in the past year
- Asthma-like Symptoms: those without an asthma diagnosis who reported wheezing or whistling in the chest in the past year

CHIS 2003 **Adults** with Asthma or Asthma-like Symptoms



CHIS 2003 **Children** with Asthma or Asthma-like Symptoms



Methods: Exposure Measures

- We used Geographic Information Systems (GIS) to link 2003 California Health Interview Survey (CHIS) respondents' residential addresses to nearby air monitoring stations:

- For the 12-months prior to respondents' interview dates, we calculated:
  - annual pollutant averages
  - number of federal/state exceedance days for pollutant concentrations
  - traffic density
  - distance from residence to roadways

Measures of Air Pollutant Exposure

Annual Average Pollutant Concentrations

- O_3
- PM_{10}
- $PM_{2.5}$
- NO_2

Exceedances of State & Federal Standards

- O_3 1-hr (State)
- O_3 8-hr (State)
- O_3 8-hr (Federal)
- NO_2 1-hr (State)
- PM_{10} 24-hr (State)
- PM_{10} 24-hr (Federal)
- $PM_{2.5}$ 24-hr (Federal)

Measures of Traffic Exposure

based on Tele Atlas Dynamap 2000 roadway map

Residential Traffic Density (TD)

- Home location overlaid with map of traffic count data
- TD = Σ Vehicle Meters Traveled (VMT)

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  area of the buffer

- VMT = annual average daily traffic count

  X road segment length

Residential Distance to Roadways

- Distance from home to nearest:
- Interstate highway
- State highway
- Major road

Asthma or Asthma-like Health Effect Measures

Lifetime Asthma

- Asthma attack(s)

Current Asthma

- ED visit(s)
- Daily medication use
- ≥2 work/school absences*
- Daily/weekly symptoms

Asthma-like Symptoms

- Wheeze
  - ≥2 wheeze attacks*
  - Sought medical attention
  - ≥2 work/school absences*

*Data not collected for teen respondents

Prevalence of Asthma Outcomes
(Current Asthma)

Outcome	Adults (≥18 years)		Children (< 18 years)	
	n	% (Weighted)	n	% (Weighted)
Asthma Attack*	1,951	35.0	664	36.0
ED visits	500	16.4	237	21.7
Daily Asthma Medication	1,653	47.6	421	37.0
Missed ≥2 Work/School Days Due to Asthma**	347	13.2	294	45.9
Daily/Weekly Asthma Symptoms	1,058	29.8	129	11.7

*Among respondents with lifetime asthma
** Data not collected for teen respondents

Disparities in Asthma Outcomes
by Sub-population **(Current Asthma)**

		Asthma Attack		ED Visits		Daily Asthma Medication		Missed ≥2 days of work/school		Daily/weekly asthma symptoms	
		Adults	Children	Adults	Children	Adults	Children	Adults	Children	Adults	Children
Demographics		%	%	%	%	%	%	%	%	%	%
Household	0 - 199 % FPL	**40.3*** **	**32.1***	**24.1 *** **	**26.4****	**53.8*** **	**45.7*** **	14.6	**54.3*** **	**35.0*** **	12.9
Federal Poverty	200 - 399 % FPL	32.6	37.1	12.8	**23.0***	46.4	34.4	13.9	**47.12***	**31.0***	12.9
Level (FPL)	≥400% FPL †	32.9	40.4	12.6	14.7	43.7	28.7	11.8	33.2	25.2	9.0
Race/ethnicity	Latino	32.6	**29.8***	**26.8*** **	25.5	44.5	**45.4****	**21.9*** **	54.1	**22.2****	11.5
	American Indian / Alaska Native	47.4	38.0			56.2				34.0	
	Asian / Pacific Islander / Other	36.8	36.8	18.0		41.0	32.5	**16.7***	35.0	**25.2***	12.8
	African American	34.3	44.2	19.3	**32.3***	**59.4****	37.6	**19.7****	48.8	30.2	
	White †	35.0	37.9	12.7	18.8	48.0	31.5	8.8	42.7	32.7	11.6

*p < 0.05, **p < 0.01, ***p < 0.001
† Reference Group

Note: Some estimates not shown due to instability.
Asthma attack prevalence estimated for those with lifetime asthma.
Missed school days estimate does not include teens.

Prevalence of Asthma-like Outcomes
(Asthma-like Symptoms)

Outcome	Adults (≥18 years)		Children (< 18 years)	
	n	% (Weighted)	n	% (Weighted)
Wheeze	4,129	11.5	951	9.9
Missed ≥2 Work/School Days Due to Wheeze*	510	16.8	313	45.4
≥2 Wheeze Attacks*	2,313	62.0	324	51.7
Sought Medical Attention for Wheezing	1,497	41.3	643	65.5

*Data not collected for teen respondents

Disparities in Asthma-like Outcomes
by Sub-population **(Asthma-like Symptoms)**

		Wheeze		Missed ≥ 2 school/work days due to wheezing		≥2 wheeze attacks		Sought medical help for breathing problem	
		Adults	Children	Adults	Children	Adults	Children	Adults	Children
Demographics		%	%	%	%	%	%	%	%
Household Federal Poverty Level (FPL)	0 - 199 % FPL	**13.4*** **	9.4	17.3	45.2	60.4	54.8	41.9	65.1
	200 - 399 % FPL	**11.7** **	9.2	15.4	47.9	63.7	56.3	40.0	66.6
	≥400% FPL†	9.8	11.2	17.3	44.0	62.7	44.3	41.6	65.1
Race/ethnicity	Latino	**9.8*** **	9.0	**24.5*** **	50.7	**51.7*** **	48.6	**46.1***	69.1
	American Indian / Alaska Native	**26.4*** **				74.9		36.0	
	Asian / Pacific Islander / Other	**7.2*** **	10.6	11.6	**29.6***	67.7	**75.5*** **	43.0	56.6
	African American	13.2	10.3	17.6	52.5	62.4	€	**49.0***	49.7
	White†	13.1	10.4	14.3	45.5	64.8	48.1	38.5	68.2

*p < 0.05, **p < 0.01, ***p < 0.001
† Reference Group

Note: Some estimates not shown due to instability.
All CHIS 2003 respondents without an asthma diagnosis were asked whether they experienced wheezing symptoms. All who said "Yes" were designated as having asthma-like symptoms.
Missed school days and ≥2 wheeze attack estimates do not include teens.

Study Hypotheses

Among those with asthma or asthma-like symptoms in California:

1. Vulnerable sub-populations (i.e. racial/ethnic minorities and those with low income) have greater exposure to air pollution.

2. Those with greater air pollution exposure are more likely to report adverse asthma and asthma-like outcomes.

3. Air pollution exposure, low socioeconomic status (SES), and "vulnerability factors" independently increase odds of negative health outcomes.

4. Increased pollutant exposure interacts with vulnerability factors resulting in a greater impact of air pollution on asthma and asthma-like outcomes.

Methods: Analyses

All analyses conducted for respondents with asthma or asthma-like symptoms, and separately for children and adults.

- **Bi-variate analyses:** testing differences in exposure estimates across sub-populations

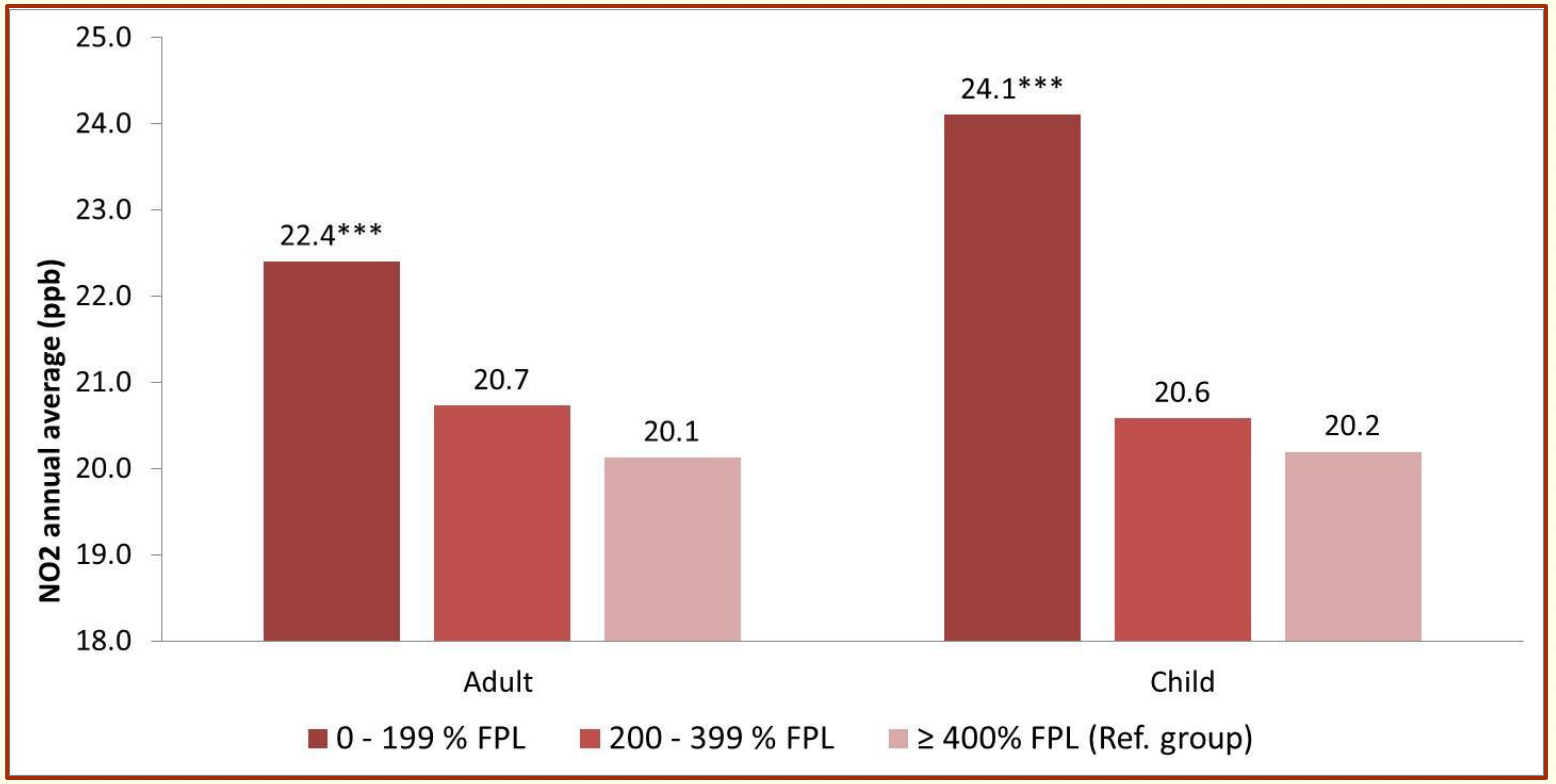
- **Logistic regression analyses, including:**
  - Pollutant-outcome analyses adjusting for potential confounders related to vulnerability
  - Interaction terms to evaluate increased vulnerability to pollutants among sub-populations
  - Sensitivity analyses on length of residence, employment status, distance from pollutant monitors, and asthma medication use

Results for Hypothesis #1

Among those with asthma or asthma-like symptoms, vulnerable sub-populations in California (e.g., racial/ethnic minorities and low-income individuals) have higher exposure to air pollution.

Disparities in Pollutant Concentration
by Federal Poverty Level **(Current Asthma)**

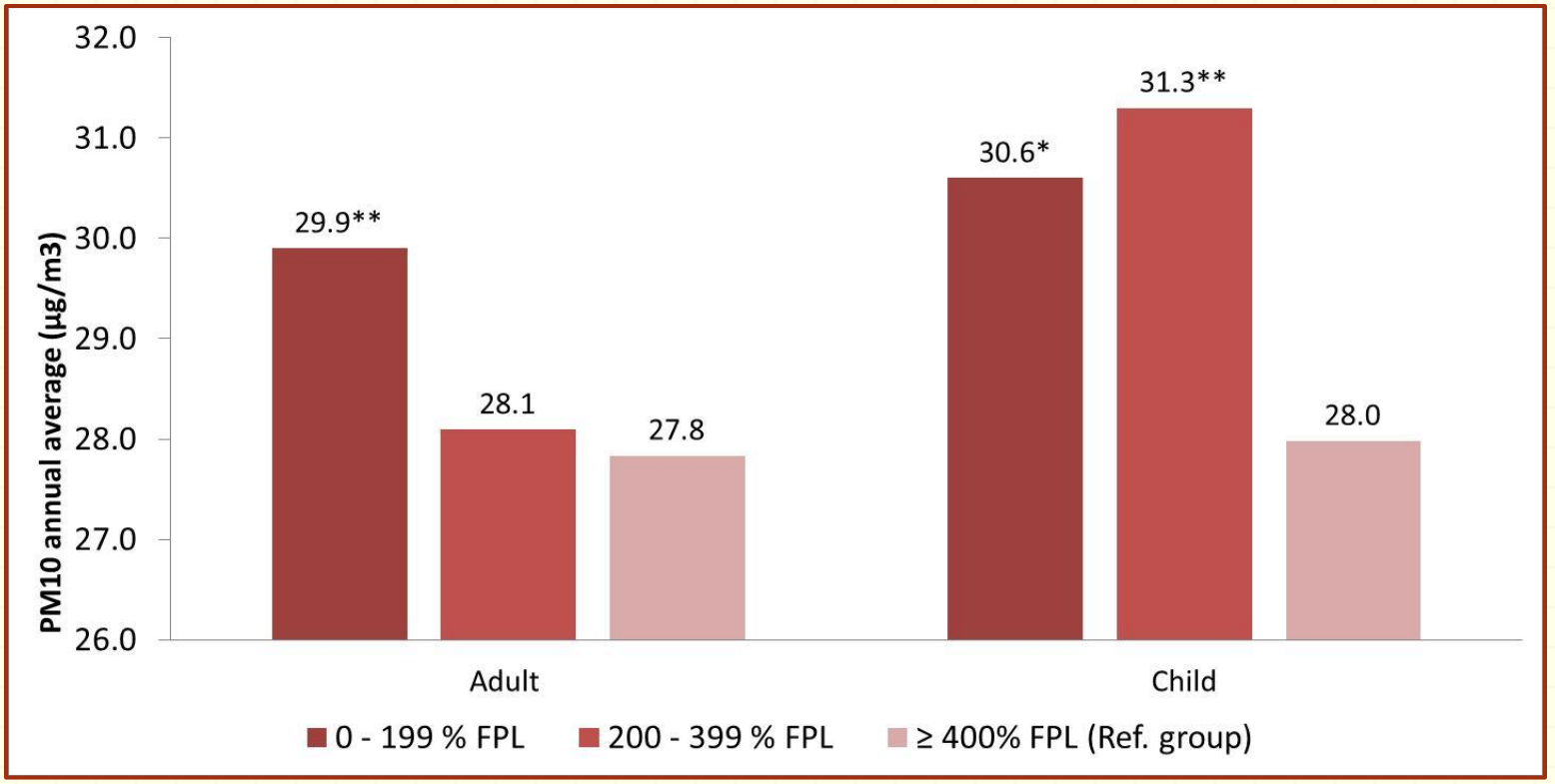
Annual average **NO_2** concentrations



*p < 0.05, **p < 0.01, ***p < 0.001

Disparities in Pollutant Concentration
by Federal Poverty Level **(Current Asthma)**

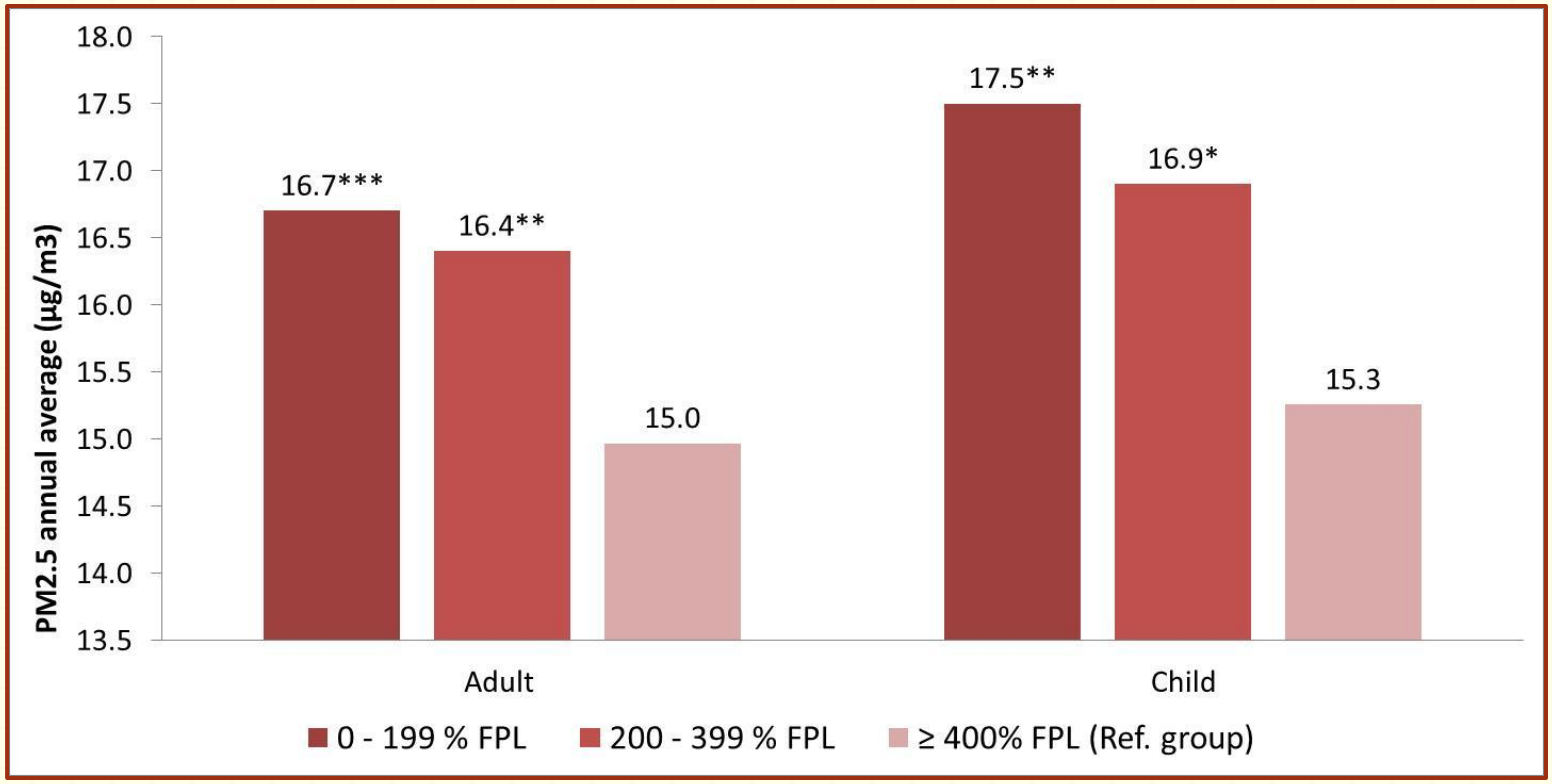
Annual average $\mathbf{PM_{10}}$ concentrations



*p < 0.05, **p < 0.01, ***p < 0.001

Disparities in Pollutant Concentration
by Federal Poverty Level **(Current Asthma)**

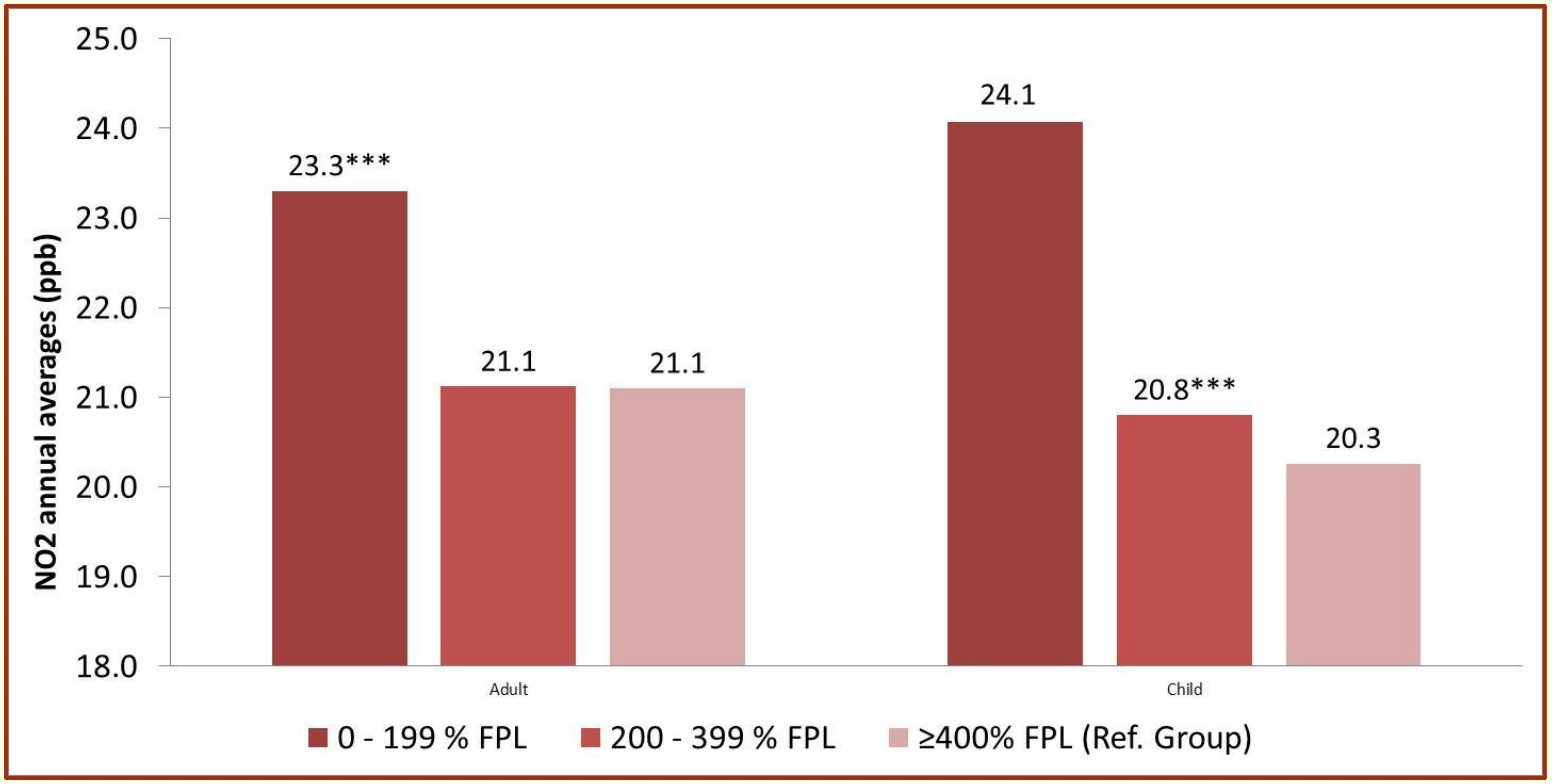
Annual average $\mathbf{PM_{2.5}}$ concentrations



*p < 0.05, **p < 0.01, ***p < 0.001

Disparities in Pollutant Concentration
by Federal Poverty Level **(Asthma-like Symptoms)**

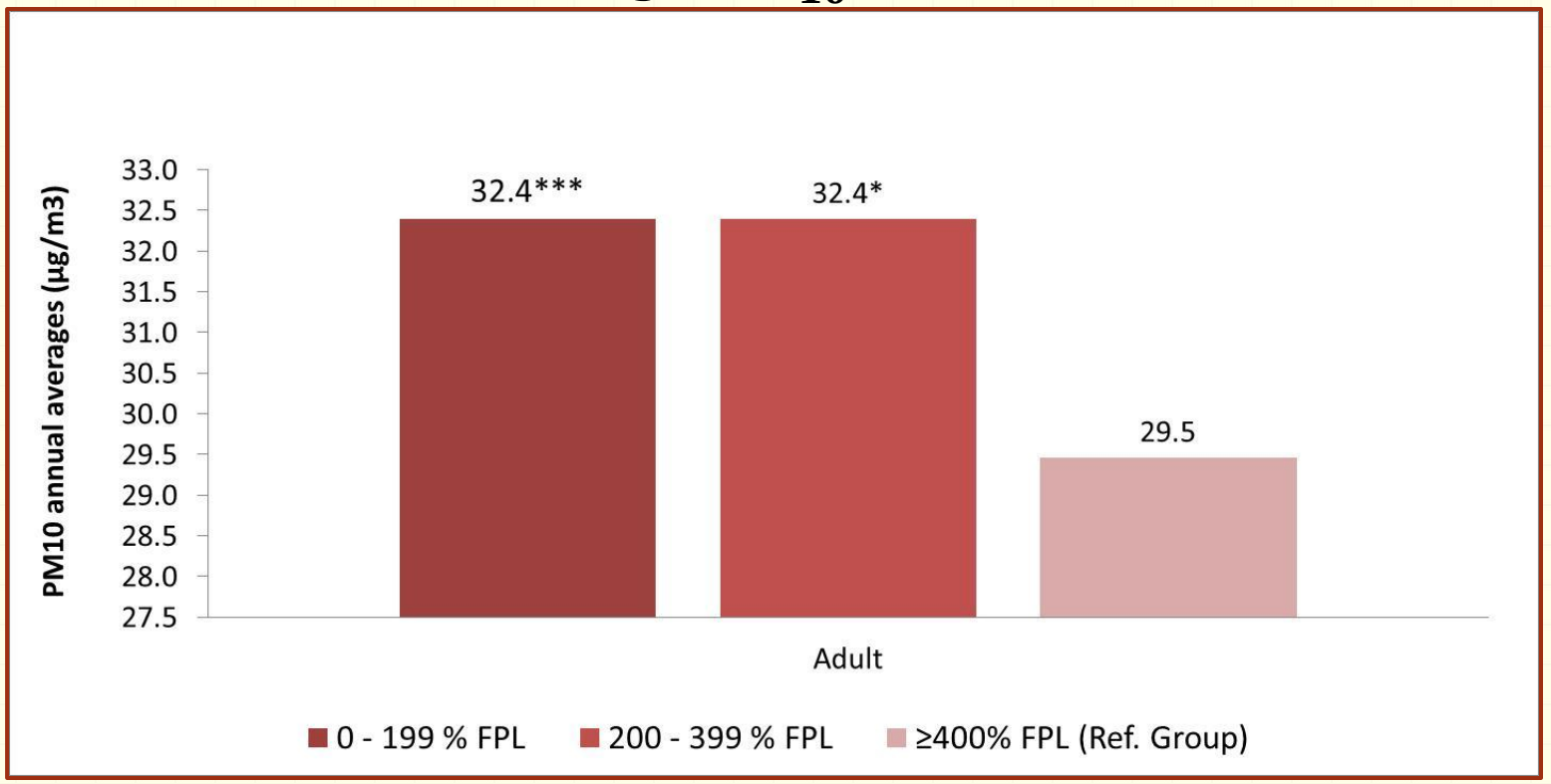
Annual average $\mathbf{NO_2}$ concentrations



*p < 0.05, **p < 0.01, ***p < 0.001

Disparities in Pollutant Concentration
by Federal Poverty Level **(Asthma-like Symptoms)**

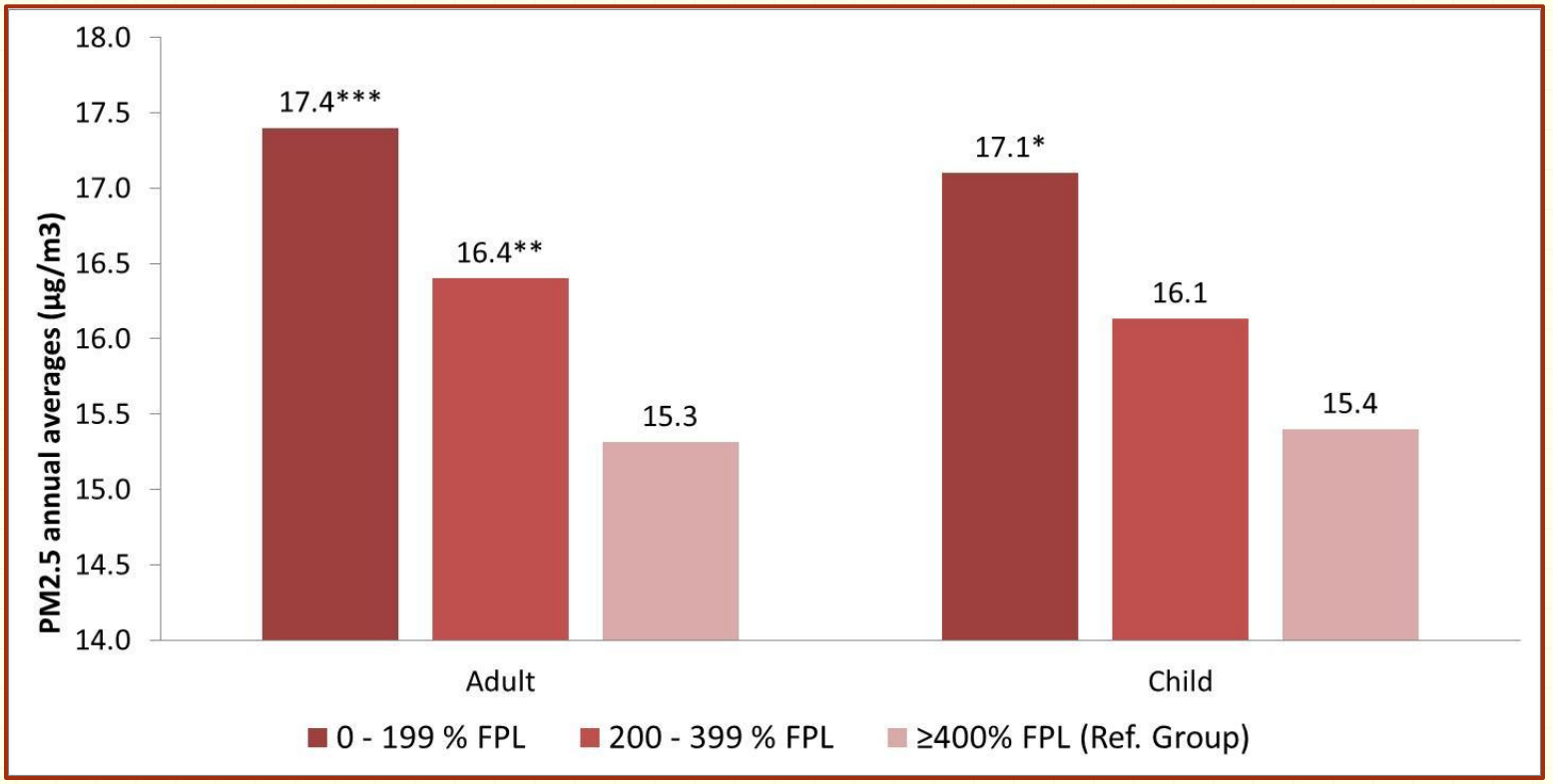
Annual average $\mathbf{PM_{10}}$ concentrations



*p < 0.05, **p < 0.01, ***p < 0.001

Disparities in Pollutant Concentration
by Federal Poverty Level **(Asthma-like Symptoms)**

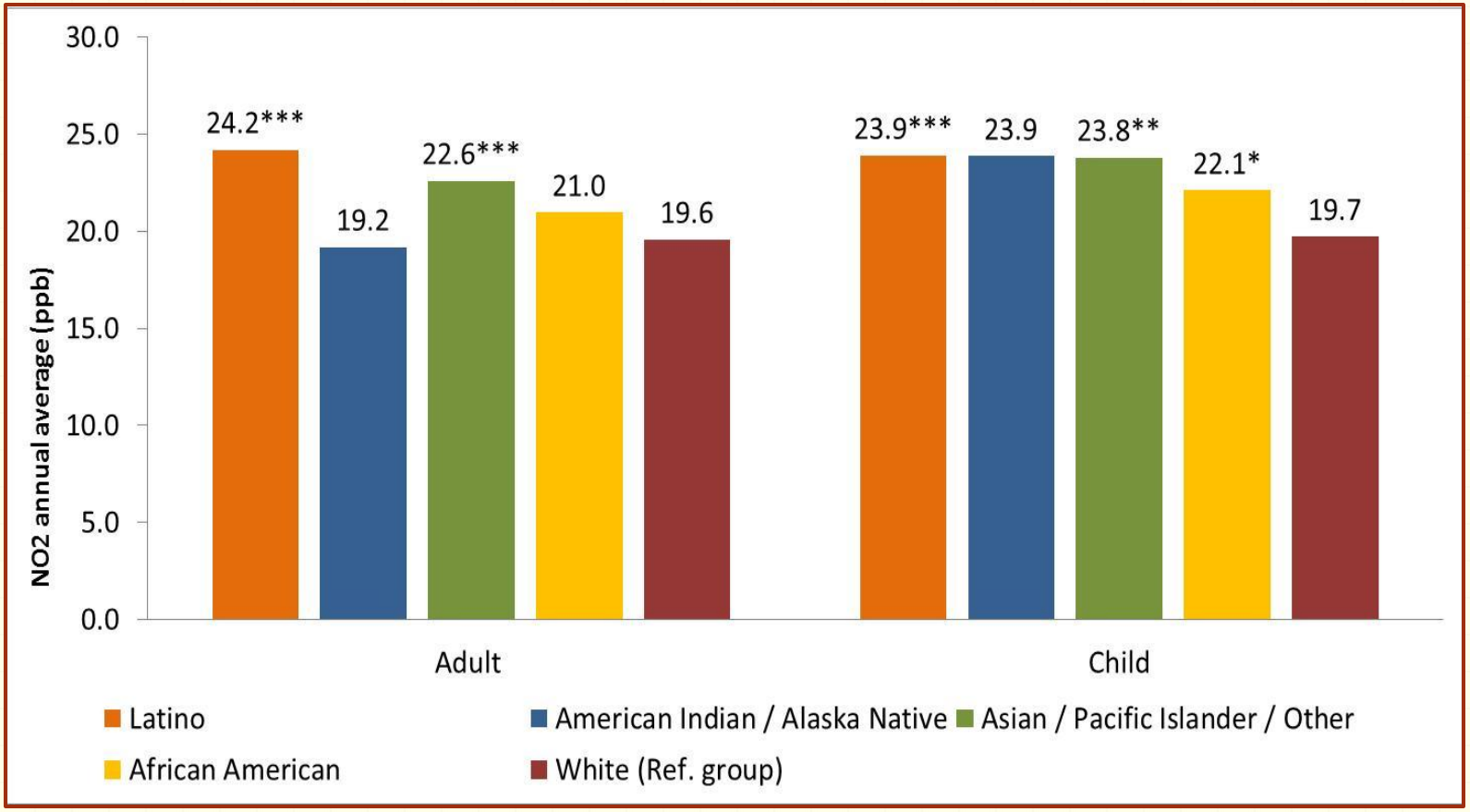
Annual average $\mathbf{PM_{2.5}}$ concentrations



*p < 0.05, **p < 0.01, ***p < 0.001

Disparities in Pollutant Concentration
by Race/Ethnicity **(Current Asthma)**

Annual average **NO_2** concentrations



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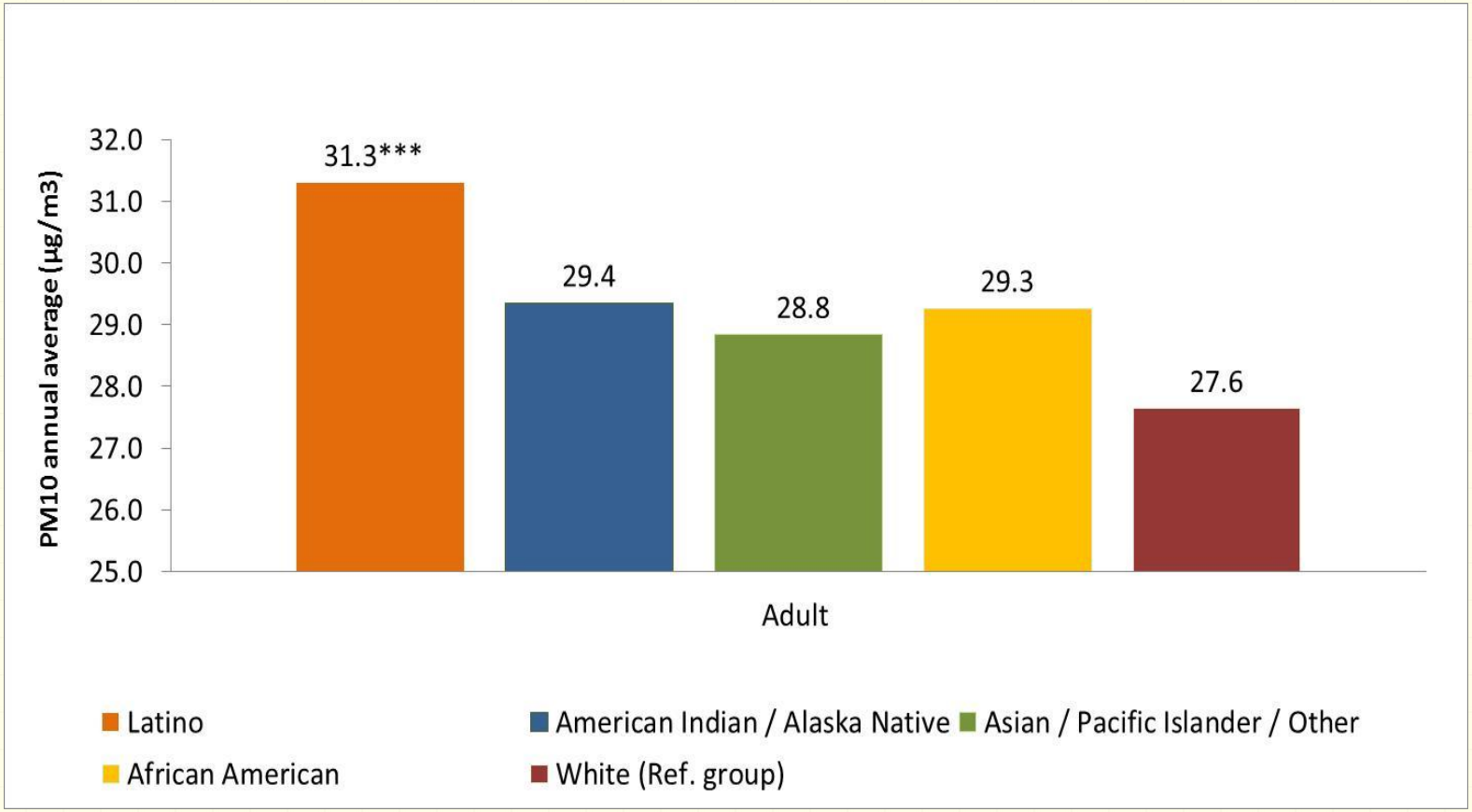
Disparities in Pollutant Concentration
by Race/Ethnicity **(Current Asthma)**

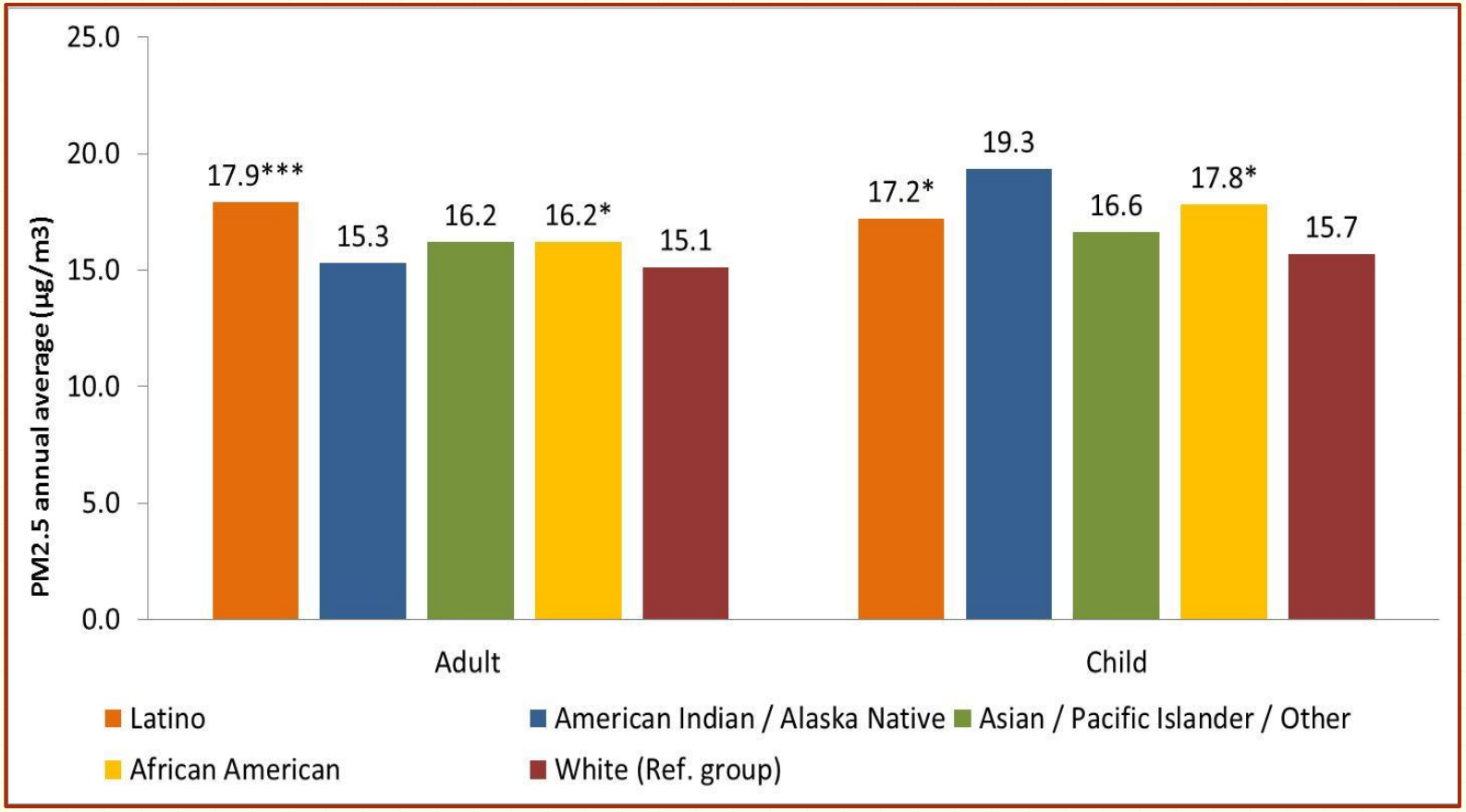
Annual average $\mathbf{PM_{10}}$ concentrations



*p < 0.05, **p < 0.01, ***p < 0.001

Disparities in Pollutant Concentration
by Race/Ethnicity **(Current Asthma)**

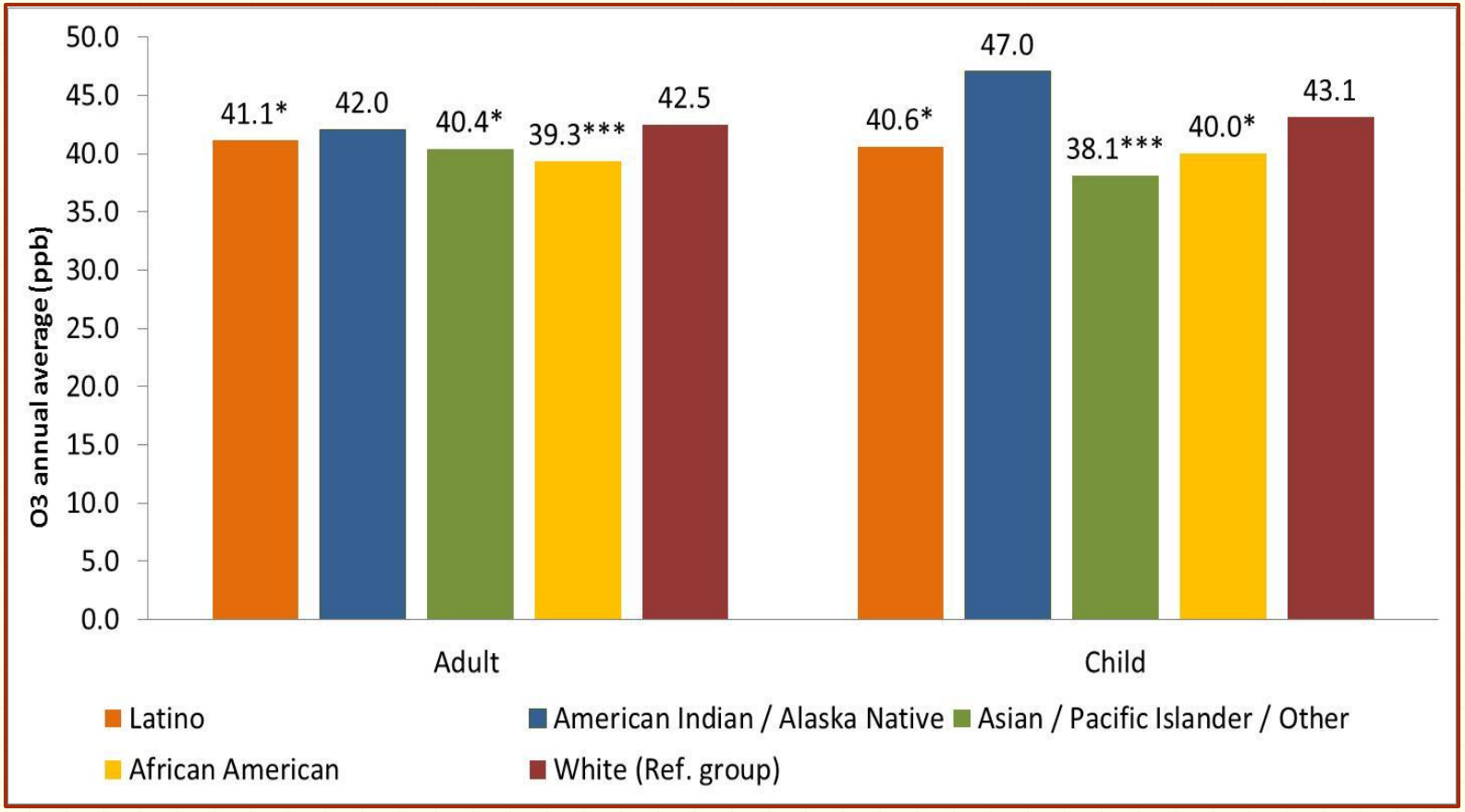
Annual average $\mathbf{PM_{2.5}}$ concentrations



*p < 0.05, **p < 0.01, ***p < 0.001

Disparities in Pollutant Concentration
by Race/Ethnicity **(Current Asthma)**

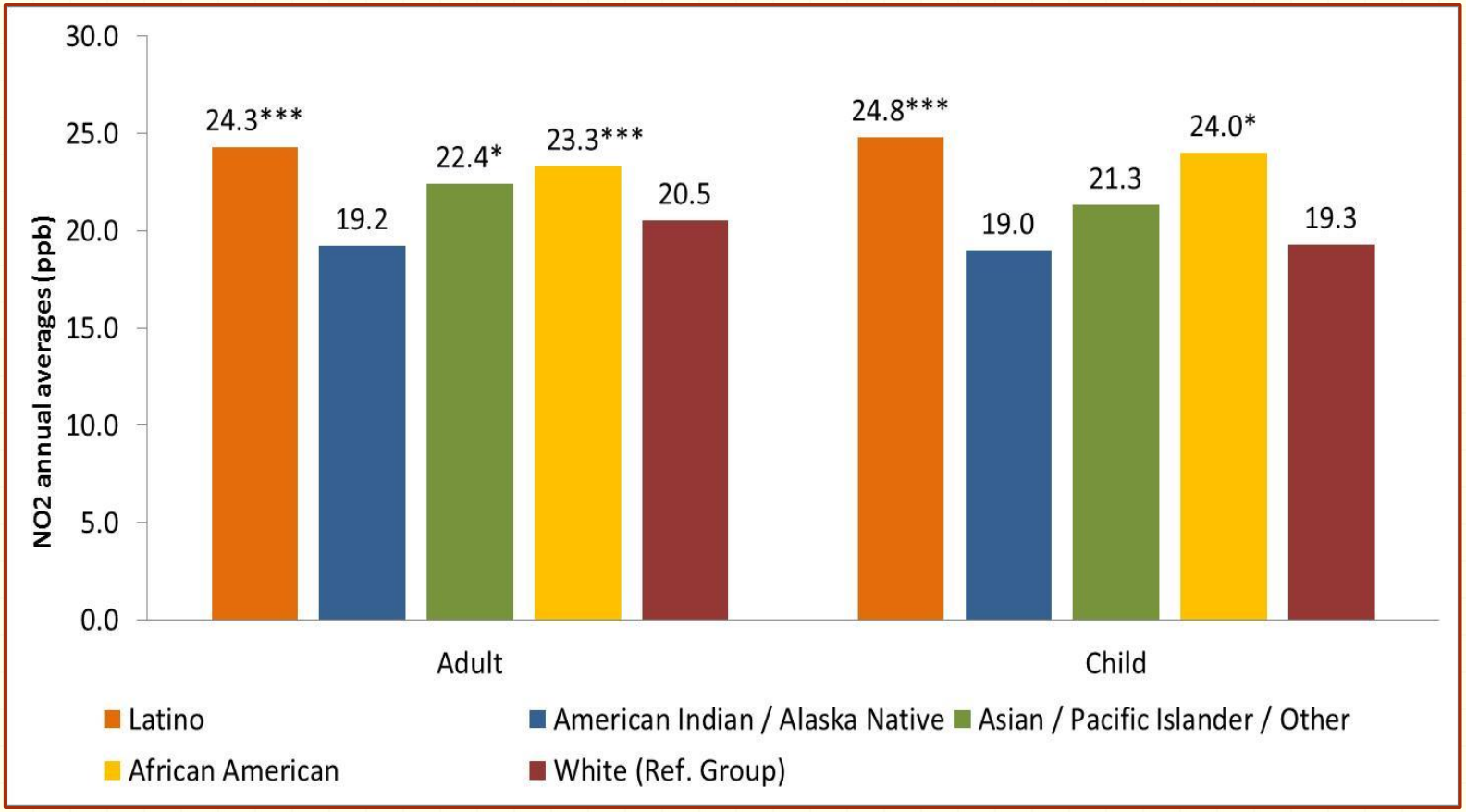
Annual average $\mathbf{O_3}$ concentrations



*p < 0.05, **p < 0.01, ***p < 0.001

Disparities in Pollutant Concentration
by Race/Ethnicity **(Asthma-like Symptoms)**

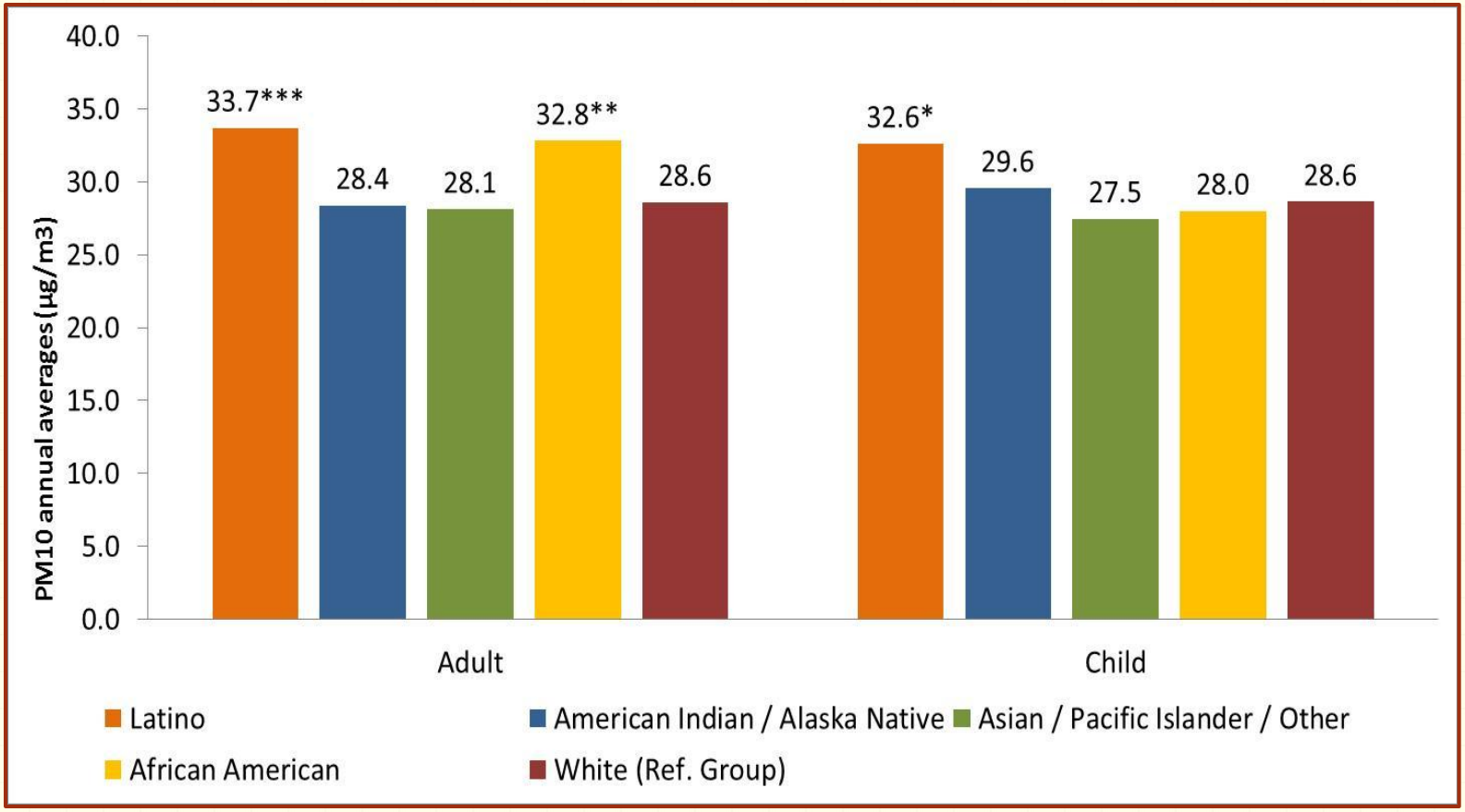
Annual average **NO_2** concentrations



*p < 0.05, **p < 0.01, ***p < 0.001

Disparities in Pollutant Concentration
by Race/Ethnicity **(Asthma-like Symptoms)**

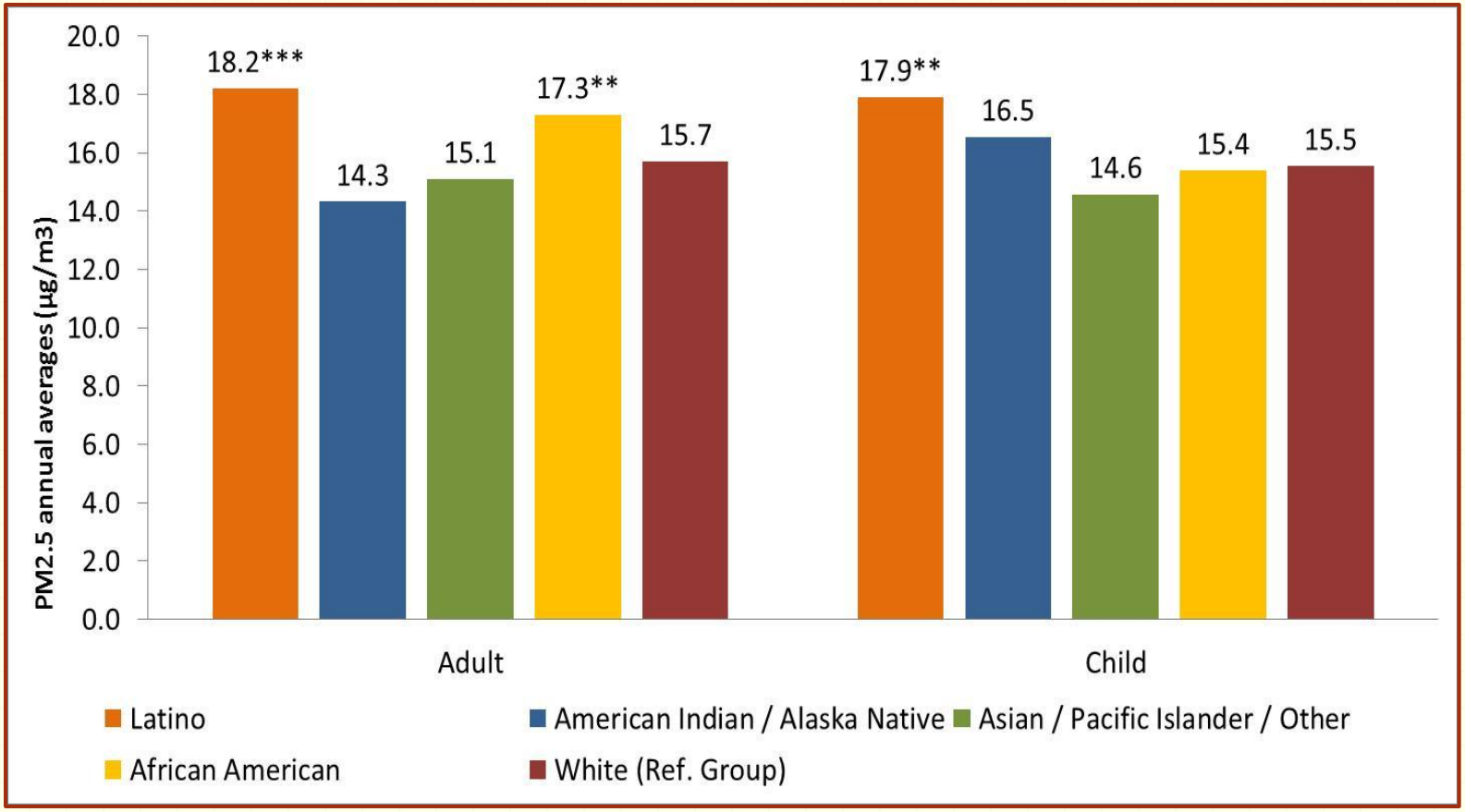
Annual average $\mathbf{PM_{10}}$ concentrations



*p < 0.05, **p < 0.01, ***p < 0.001

Disparities in Pollutant Concentration
by Race/Ethnicity **(Asthma-like Symptoms)**

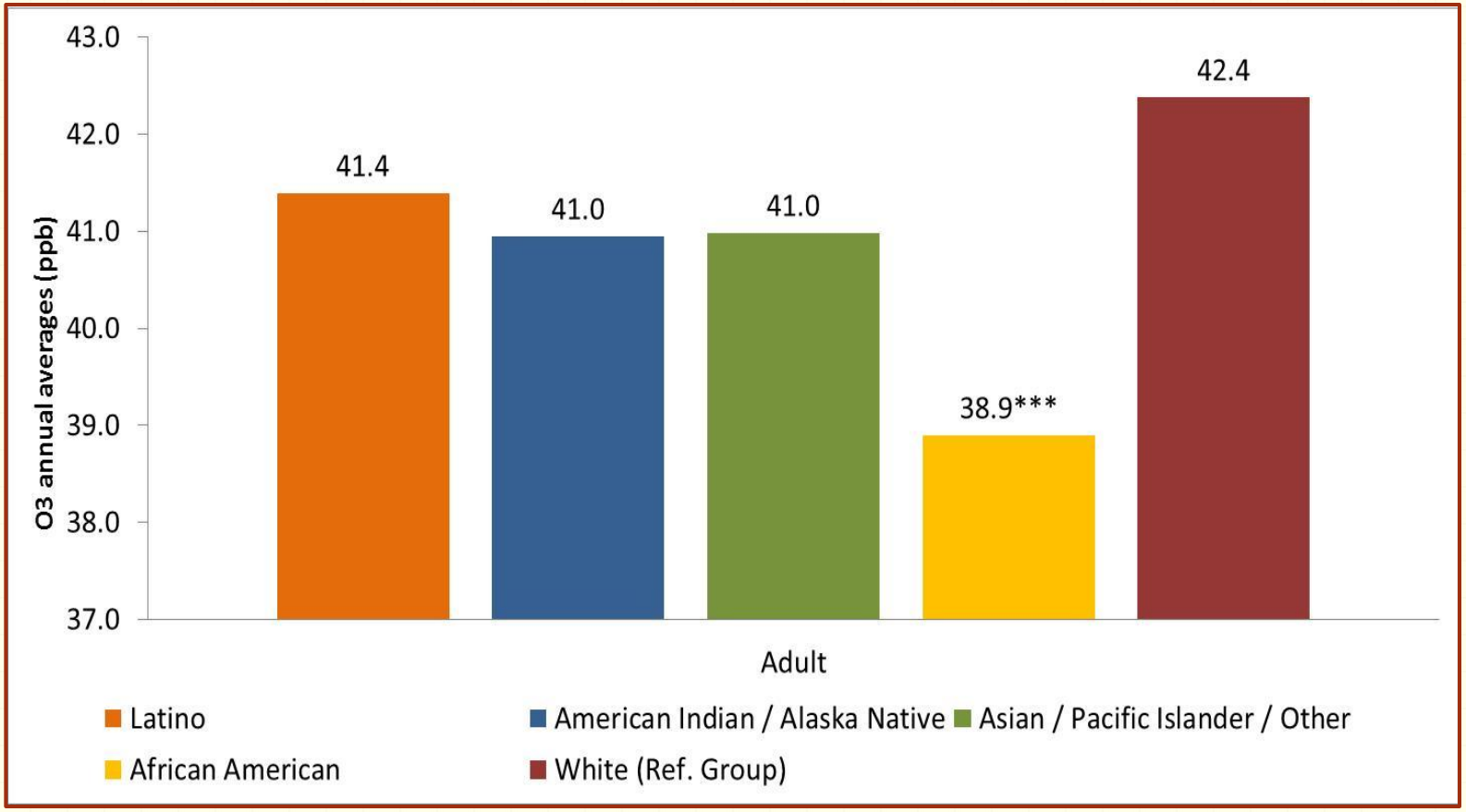
Annual average $\mathbf{PM_{2.5}}$ concentrations



*p < 0.05, **p < 0.01, ***p < 0.001

Disparities in Pollutant Concentration
by Race/Ethnicity **(Asthma-like Symptoms)**

Annual average $\mathbf{O_3}$ concentrations



*p < 0.05, **p < 0.01, ***p < 0.001

Disparities in Traffic Exposure
by Sub-populations **(Current Asthma)**

Average residential traffic density

		Teleatlas Traffic Density Within 750-ft Buffer (VMT/day/meter^2)	
		Adult	Child
Demographics		mean	mean
Household Federal Poverty Level (FPL)	0 - 199 % FPL	66.6	**84.6*****
	200 - 399 % FPL	68.6	**70.2***
	≥400% FPL†	64.1	**52.7**
Race/Ethnicity	Latino	67.0	**93.6*****
	American Indian / Alaska Native	58.6	93.0
	Asian / Pacific Islander / Other	88.9	54.3
	African American	**76.6***	**89.8****
	White†	60.2	53.2

*p < 0.05, **p < 0.01, ***p < 0.001

Disparities in Distance to Roadways
by Federal Poverty Level **(Current Asthma)**

Percent of people with residence near roadways

		State Highway < 300 m		Interstate Highway < 300 m		Major Road < 50 m	
		Adult	Child	Adult	Child	Adult	Child
Demographics		%	%	%	%	%	%
Household Federal Poverty Level (FPL)	0 - 199 % FPL	7.0	**9.5***	9.2	**16.4****	**26.4*****	**24.7***
	200 - 399 % FPL	5.2	3.3	11.0	12.8	**23.7***	20.7
	≥400% FPL†	4.3	2.6	9.8	6.3	17.5	15.3

*p < 0.05, **p < 0.01, ***p < 0.001

† Reference Group

Results for Hypothesis #2

Individuals with asthma exposed to higher levels of air pollution are more likely to report adverse asthma outcomes, such as:

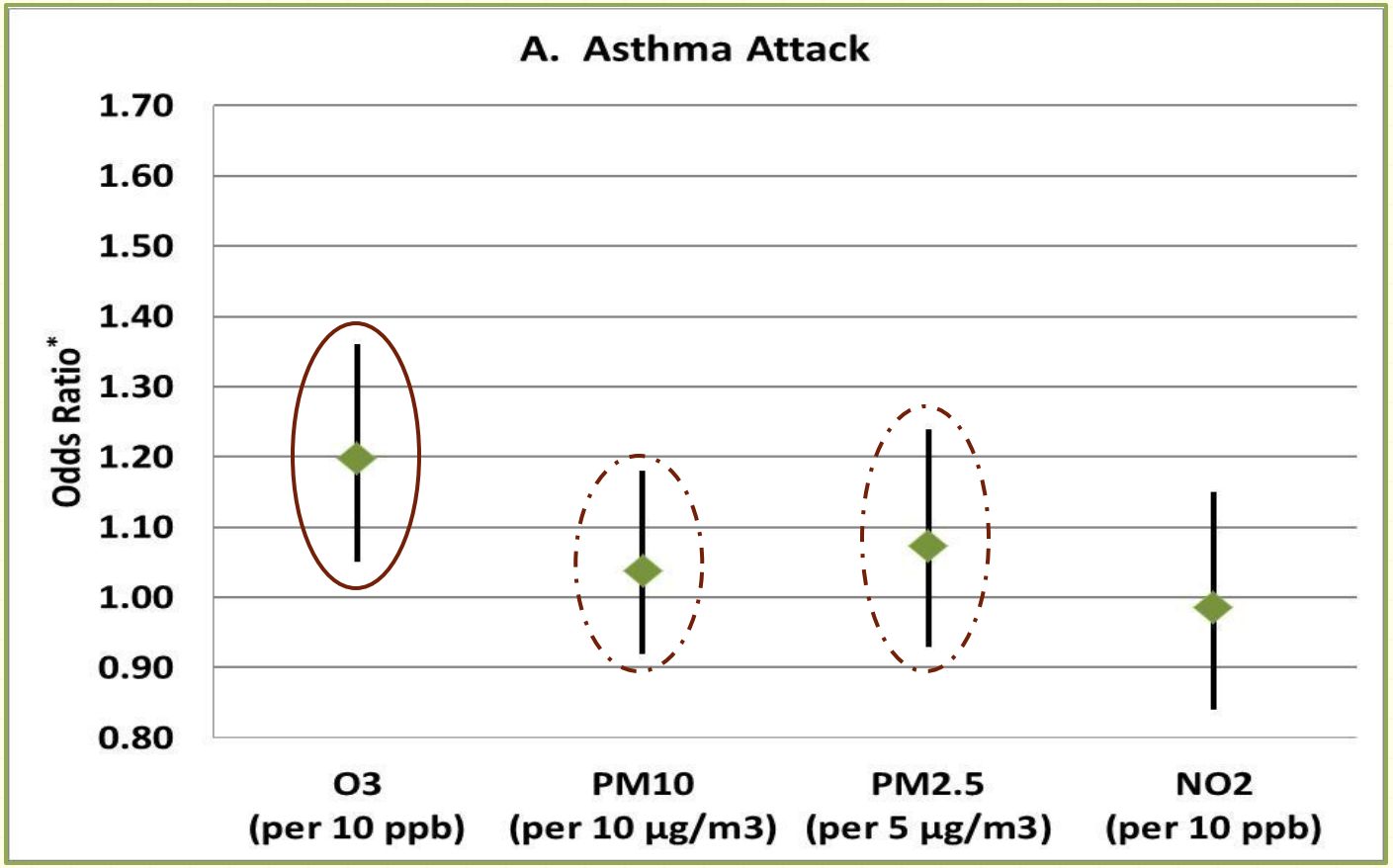
- asthma attacks or episodes
- asthma emergency department (ED) visits
- use of daily medication to control asthma
- school or work absences
- daily/weekly asthma symptoms.

Individuals with asthma-like symptoms exposed to higher levels of air pollution are more likely to report:

- wheezing or whistling sound in the chest
- attacks of wheezing or whistling
- seeking medical care for such symptoms
- work/school days missed due to such symptoms

Pollutants and Asthma Attacks
(Lifetime Asthma, Adults)

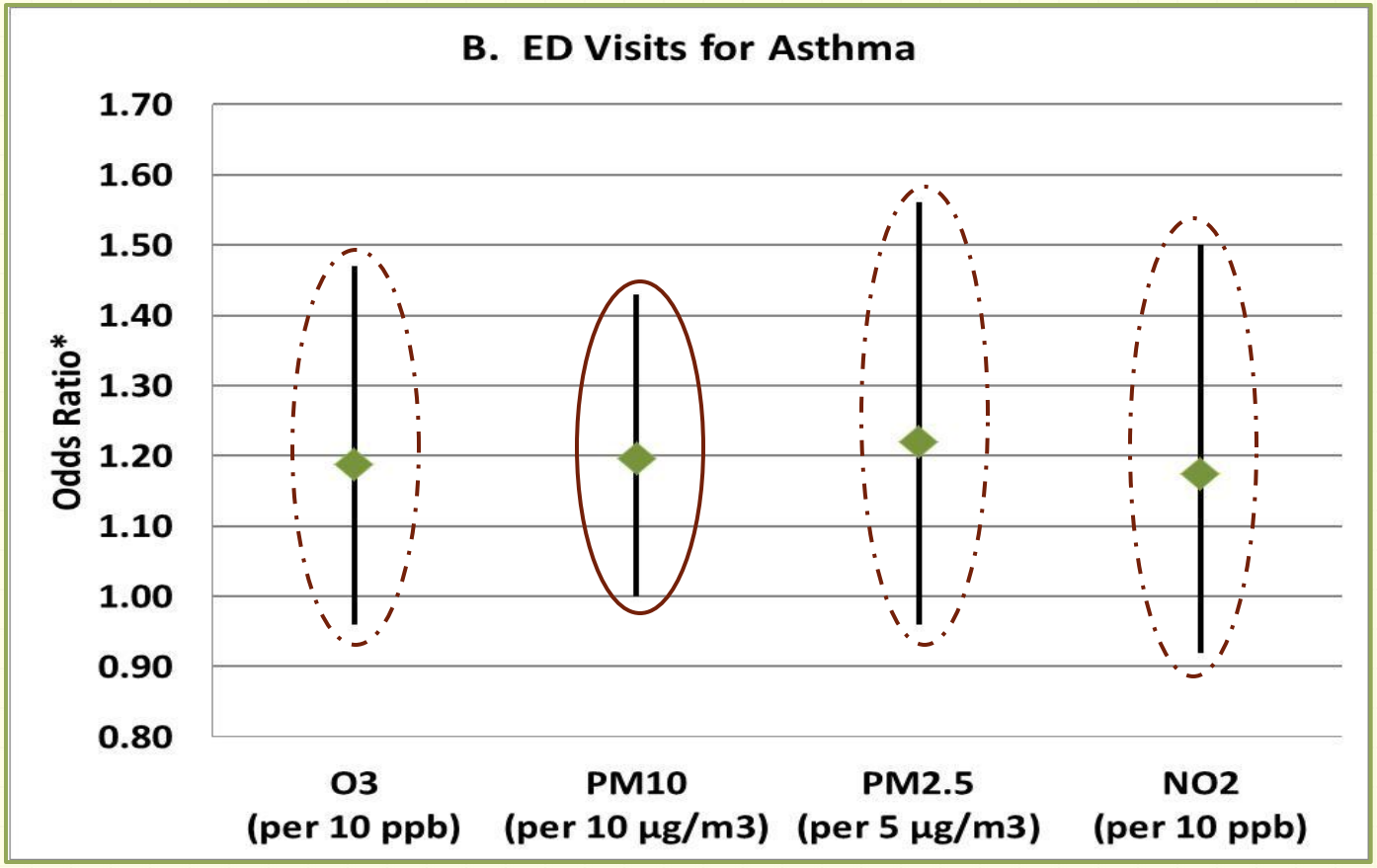
Associations between 12-month Pollutant Averages and Asthma Attacks



*Adjusted for age, sex, race and federal poverty level

Pollutants and ED Visits
(Current Asthma, Adults)

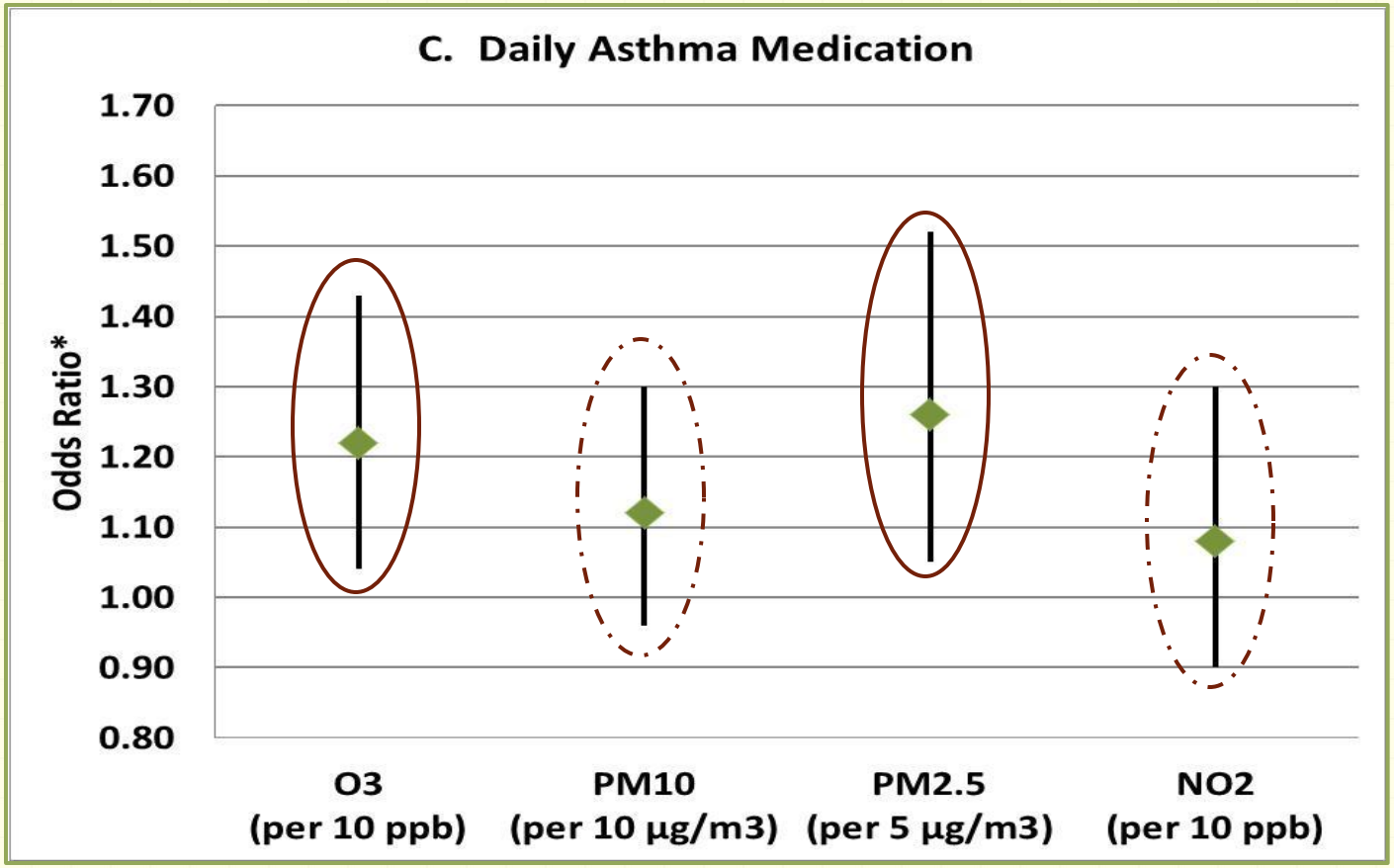
Associations between 12-month Pollutant Averages and ED Visits



*Adjusted for age, sex, race and federal poverty level

Pollutants and Asthma Medication Use
(Current Asthma, Adults)

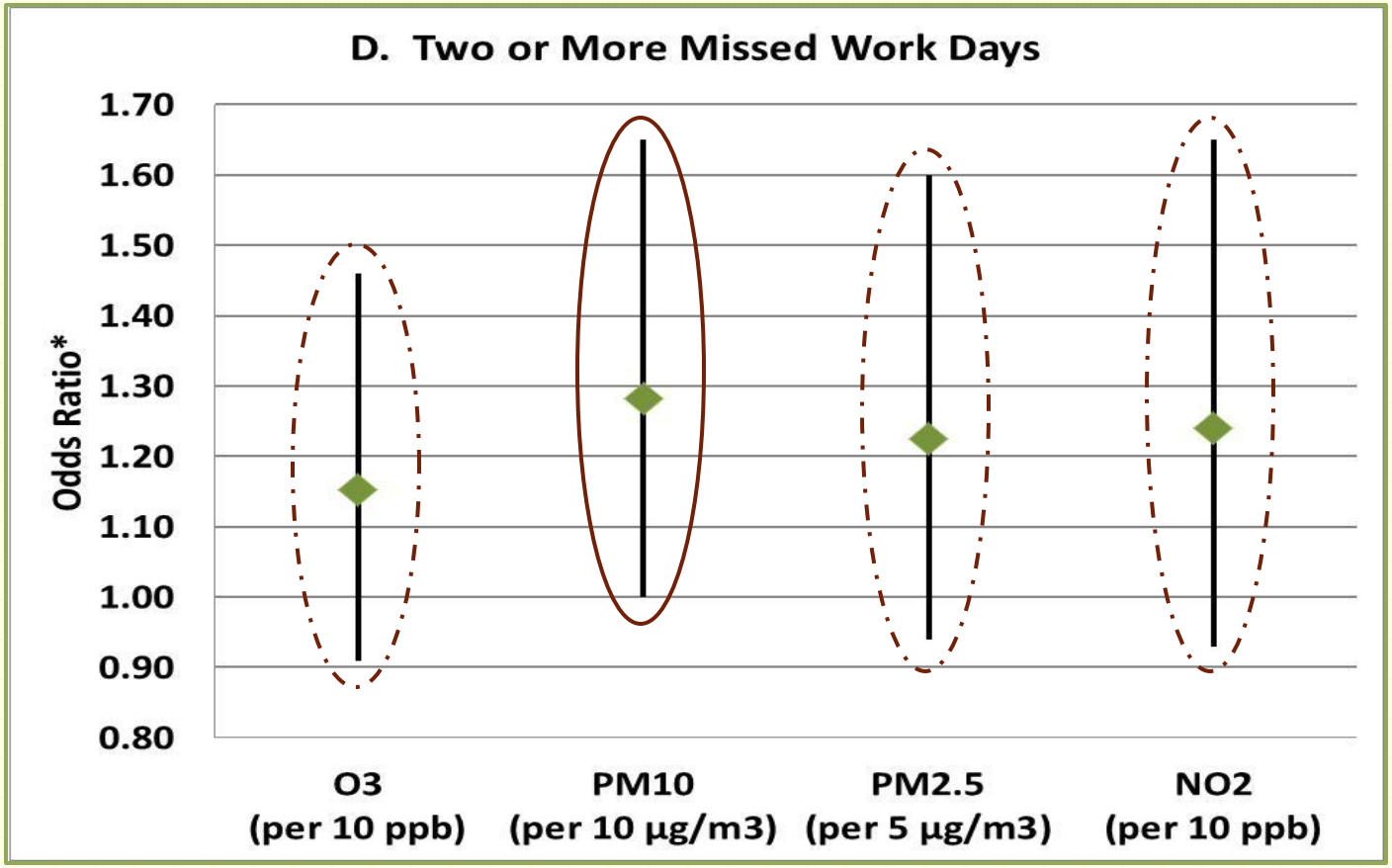
Associations between 12-month Pollutant Averages and Daily Asthma Medication Use



*Adjusted for age, sex, race and federal poverty level

Pollutants and Work Absences
(Current Asthma, Adults)

Associations between 12-month Pollutant Averages and ≥ 2 Missed Work Days



*Adjusted for age, sex, race and federal poverty level

Pollutants and Asthma-like Outcomes (Asthma-like Symptoms)

Associations between 12-month Pollutant Averages and Asthma-like Outcomes

	Wheeze				Missed ≥2 School/Work Days Due to Wheezing				≥2 Wheeze Attacks				Sought Medical Help for Breathing Problem			
Pollutant	Cases	Non-Cases	OR	95% C.I.	Cases	Non-Cases	OR	95% C.I.	Cases	Non-Cases	OR[d]	95% C.I.	Cases	Non-Cases	OR	95% C.I.
Adults																
O_3 (per 10 ppb)	2,044	14,824	**1.09**	[1.01, 1.18]	258	1,296	0.91	[0.74, 1.12]	1,121	657	**1.11**	[0.94, 1.30]	739	1,039	**1.06**	[0.91, 1.24]
PM_{10} (per 10 µg/m^3)	1,614	11,229	**1.09**	[1.01, 1.18]	198	1,027	0.84	[0.66, 1.06]	912	488	**1.10**	[0.94, 1.29]	577	823	**1.09**	[0.94, 1.27]
$PM_{2.5}$ (per 5 µg/m^3)	1,253	9,331	**1.07**	[0.97, 1.17]	162	797	0.88	[0.69, 1.12]	691	396	1.00	[0.83, 1.19]	462	625	1.06	[0.89, 1.26]
NO_2 (per 10 ppb)	1,687	12,534	0.93	[0.86, 1.02]	222	1,061	0.73	[0.56, 0.96]	905	566	**1.09**	[0.91, 1.30]	622	849	0.93	[0.78, 1.11]
Children																
O_3 (per 10 ppb)	441	4,109	**1.09**	[0.92, 1.29]	143	167	0.96	[0.67, 1.36]	157	153	**1.29**	[0.92, 1.81]	295	146	0.99	[0.72, 1.36]
NO_2 (per 10 ppb)	364	3,504	0.94	[0.79, 1.11]	113	146	1.25	[0.82, 1.90]	134	125	1.02	[0.69, 1.50]	243	121	**1.33**	[0.90, 1.98]

Adjusted for age, sex, race and federal poverty level.

Note: All CHIS 2003 respondents without an asthma diagnosis were asked whether they experienced wheezing symptoms. All who said "Yes" were designated as having asthma-like symptoms. Missed school days and ≥2 wheeze attack estimates do not include teens.

Traffic Exposures and Asthma Outcomes **(Current Asthma)**

Associations for traffic density/distance to roadway and asthma outcomes

		ED Visit for Asthma		Daily Asthma Medication	
Exposure		OR*	95% C.I.	OR*	95% C.I.
Traffic Density**		Adults		Children	
	Dense Traffic < 750ft (25th < 50th percentile)	0.89	[0.59, 1.36]	1.17	[0.69, 1.97]
	Dense Traffic < 750ft (50th < 75th percentile)	**1.48**	[1.02, 2.16]	**1.58**	[0.94, 2.66]
	Dense Traffic < 750ft (≥75th percentile)	1.05	[0.70, 1.58]	1.43	[0.83, 2.47]
Proximity to Roadway***		Adults		Adults	
	State Highway < 300 m	0.77	[0.42, 1.41]	0.91	[0.55, 1.52]
	Interstate Highway < 300 m	**1.51**	[0.91, 2.48]	**1.34**	[0.95, 1.90]
	Major Road < 50 m	1.02	[0.69, 1.50]	0.96	[0.75, 1.24]

*Adjusted for age, sex, race and federal poverty level
**Reference Group: <25th percentile
***Reference Group: >300 m or >50 m, as noted

Results for Hypothesis #3

Air pollution exposures, low SES, and certain "vulnerability factors" associated with low SES, independently increase individual odds of negative asthma or asthma-like outcomes.

Vulnerability factors examined were:

- **co-morbidity:** diabetes , heart disease
- **access to care:** health insurance status, usual source of care
- **disease management/asthma severity:** taking daily medication to control asthma, receiving an asthma management plan, adult or child onset of asthma
- **health behaviors:** being overweight/obese, smoking, walking outdoor
- **exposure to indoor triggers:** environmental tobacco smoke and indoor allergens, such as cockroaches, dogs and cats; employment status
- **housing conditions:** single family dwelling or apartment, crowding

ED Visits, O_3 and Vulnerability Factors (Current Asthma, Adults)

Associations between asthma-related ED visits and vulnerability factors by pollutant

	O_3 (per 10 ppb)								
	Model 1			Model 2*			Model 3**		
Vulnerability Characteristic	OR	95% C.I.		OR	95% C.I.		OR	95% C.I.	
12-Month Pollutant Average	**1.19**	0.96	1.47	**1.18**	0.95	1.47	**1.15**	0.91	1.45
Age (Ref. ≥65)									
18 - 34	1.09	0.61	1.93	1.49	0.78	2.85	**2.05**	1.00	4.20
35 - 64	**1.91**	1.15	3.20	**2.26**	1.30	3.94	**2.33**	1.29	4.19
Race (Ref. White)									
African American	**1.86**	1.04	3.32	**1.76**	0.97	3.20	**1.40**	0.73	2.68
American Indian / Alaska Native	1.51	0.43	5.29	1.46	0.42	5.16	0.96	0.29	3.16
Asian / Pacific Islander / Other	1.26	0.71	2.26	1.38	0.77	2.47	1.41	0.79	2.51
Latino	**2.03**	1.27	3.23	**2.08**	1.30	3.35	**2.23**	1.32	3.78
Poverty (Ref. ≥400% FPL)									
0 - 199% FPL	**1.93**	1.26	2.97	**1.62**	1.02	2.57	**1.82**	1.12	2.95
200 - 399% FPL	1.14	0.69	1.89	1.07	0.64	1.80	1.11	0.68	1.83
Sex									
Female vs. Male	**1.45**	0.97	2.18	**1.46**	0.97	2.21	**1.37**	0.89	2.10
Heart Disease									
Yes vs No				**1.69**	1.01	2.84			
Onset of Asthma									
Adult vs Child							**1.65**	1.08	2.54
Daily Asthma Medication									
No vs Yes							**0.35**	0.23	0.52
Asthma Management Plan									
No vs Yes							**0.52**	0.36	0.76

*Model 2 also controlled for insurance status, obesity, heart disease, smoking status, and employment status.

**Model 3 also controlled for urban/rural residency, usual source of care, delay in care, onset of asthma, daily asthma medication, asthma management plan, household smoking, dog/cat in home, cockroaches in home, housing type, household crowding, diabetes, and walking.

ED Visits, PM_{10} and Vulnerability Factors **(Current Asthma, Adults)**

Associations between asthma-related ED visits and vulnerability factors by pollutant

	PM_{10} (per 10 µg/m^3)								
	Model 1			Model 2*			Model 3**		
Vulnerability Characteristic	OR	95% C.I.		OR	95% C.I.		OR	95% C.I.	
12-Month Pollutant Average	**1.20**	1.00	1.43	**1.18**	0.99	1.42	**1.25**	1.03	1.51
Age (Ref. ≥65)									
18 - 34	1.00	0.53	1.88	1.44	0.72	2.90	1.91	0.88	4.16
35 - 64	**1.76**	0.99	3.13	**2.19**	1.20	4.00	**2.29**	1.19	4.41
Race (Ref. White)									
African American	1.42	0.74	2.71	1.30	0.67	2.53	1.16	0.58	2.29
American Indian / Alaska Native	1.36	0.38	4.93	1.27	0.33	4.88	0.83	0.24	2.91
Asian / Pacific Islander / Other	0.80	0.42	1.54	0.84	0.44	1.59	0.90	0.45	1.79
Latino	**2.42**	1.46	4.00	**2.46**	1.47	4.12	**2.40**	1.37	4.22
Poverty (Ref. ≥400% FPL)									
0 - 199% FPL	**2.02**	1.27	3.20	**1.72**	1.06	2.80	**1.95**	1.15	3.31
200 - 399% FPL	1.34	0.79	2.27	1.31	0.76	2.25	1.37	0.79	2.39
Sex									
Female vs. Male	1.28	0.83	1.97	1.23	0.80	1.88	1.25	0.80	1.96
Heart Disease									
Yes vs No				**2.07**	1.22	3.52			
Onset of Asthma									
Adult vs Child							**1.50**	0.94	2.39
Daily Asthma Medication									
No vs Yes							**0.30**	0.20	0.47
Asthma Management Plan									
No vs Yes							**0.56**	0.37	0.84

*Model 2 also controlled for insurance status, obesity, heart disease, smoking status, and employment status.

**Model 3 also controlled for urban/rural residency, usual source of care, delay in care, onset of asthma, daily asthma medication, asthma management plan, household smoking, dog/cat in home, cockroaches in home, housing type, household crowding, diabetes, and walking

ED Visits, $PM_{2.5}$ and Vulnerability Factors (Current Asthma, Adults)

Associations between asthma-related ED visits and vulnerability factors by pollutant

	$PM_{2.5}$ (per 5 µg/m^3)								
	Model 1			Model 2*			Model 3**		
Vulnerability Characteristic	OR	95% C.I.		OR	95% C.I.		OR	95% C.I.	
12-Month Pollutant Average	**1.22**	0.96	1.56	**1.21**	0.95	1.54	**1.20**	0.92	1.56
Age (Ref. ≥65)									
18 - 34	0.94	0.45	1.93	1.66	0.76	3.63	1.31	0.57	2.99
35 - 64	1.64	0.86	3.15	**2.20**	1.13	4.26	**1.88**	0.94	3.76
Race (Ref. White)									
African American	**1.92**	0.99	3.71	**1.95**	0.98	3.87	**1.38**	0.71	2.67
American Indian / Alaska Native	0.97	0.16	5.95	0.89	0.14	5.58	0.59	0.10	3.34
Asian / Pacific Islander / Other	0.96	0.47	1.96	1.08	0.52	2.23	0.92	0.46	1.84
Latino	**2.03**	1.18	3.49	**2.38**	1.35	4.22	**2.05**	1.09	3.88
Poverty (Ref. ≥400% FPL)									
0 - 199% FPL	**1.84**	1.11	3.03	**1.51**	0.90	2.54	**1.64**	0.93	2.90
200 - 399% FPL	1.09	0.57	2.06	1.09	0.58	2.05	0.98	0.51	1.90
Sex									
Female vs. Male	1.45	0.89	2.37	**1.50**	0.91	2.45	1.51	0.89	2.55
Heart Disease									
Yes vs No				**2.12**	1.20	3.73			
Onset of Asthma									
Adult vs Child									
Daily Asthma Medication									
No vs Yes							**0.29**	0.17	0.49
Asthma Management Plan									
No vs Yes							**0.63**	0.40	1.00

*Model 2 also controlled for insurance status, obesity, heart disease, smoking status, and employment status.

**Model 3 also controlled for urban/rural residency, usual source of care, delay in care, onset of asthma, daily asthma medication, asthma management plan, household smoking, dog/cat in home, cockroaches in home, housing type, household crowding, diabetes, and walking.

Daily Medication Use, $PM_{2.5}$ and Vulnerability Factors **(Current Asthma, Children)**

Associations between daily asthma medication use and vulnerability factors by pollutant

		$PM_{2.5}$ (per 5 µg/m^3)								
		Model 1			Model 2*			Model 3**		
Vulnerability Characteristic		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.	
12-Month Pollutant Average		1.20	0.88	1.63	1.20	0.87	1.64	**1.28**	0.93	1.76
Age (Ref. 6-11)										
	≤ 6	0.89	0.40	1.99	0.89	0.40	1.99	1.04	0.46	2.36
	12 - 17	1.07	0.56	2.07	1.07	0.55	2.09	1.51	0.74	3.12
Race (Ref. White)										
	African American	1.16	0.46	2.92	1.15	0.43	3.07	1.03	0.40	2.71
	American Indian / Alaska Native	1.11	0.15	8.44	1.11	0.14	8.82	0.84	0.11	6.26
	Asian / Pacific Islander / Other	0.92	0.34	2.49	0.97	0.36	2.60	0.86	0.32	2.29
	Latino	1.43	0.66	3.10	1.49	0.68	3.26	1.31	0.57	3.00
Poverty (Ref. ≥400% FPL)										
	0 - 199% FPL	**2.64**	1.22	5.72	**2.51**	1.14	5.56	**3.21**	1.40	7.39
	200 - 399% FPL	**3.00**	1.46	6.14	**2.86**	1.40	5.87	**3.56**	1.66	7.60
Sex										
	Female vs. Male	0.96	0.52	1.75	0.96	0.52	1.76	0.92	0.51	1.69
Asthma Management Plan										
	No vs Yes							**0.38**	0.19	0.75

*Model 2 also controlled for household smoking, dog/cat in home, cockroaches in home and insurance status.

**Model 3 also controlled for urban/rural residency, delay in care, asthma management plan, household smoking, and housing type.

Wheeze Attacks, O_3 and Vulnerability Factors **(Asthma-like Symptoms, Adults)**

Associations between ≥2 wheeze attacks and vulnerability factors by pollutant

		O^3 (per 10 ppb)								
		Model 1[b] (1121, 657)[e]			Model 2[c] (1115, 652)[e]			Model 3[d] (1105, 647)[e]		
Vulnerability Characteristic		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.	
12-Month Pollutant Average[f]		1.11	0.94	1.30	1.12	0.95	1.32	1.12	0.95	1.31
Age (Ref. ≥65)										
	18 - 34	0.85	0.57	1.27	1.17	0.72	1.88	0.63	0.40	0.98
	35 - 64	1.22	0.86	1.72	1.63	1.08	2.44	0.98	0.68	1.41
Race (Ref. White)										
	African American	0.94	0.57	1.54	0.97	0.59	1.62	1.05	0.62	1.77
	American Indian / Alaska Native	1.83	0.73	4.59	2.00	0.78	5.17	1.85	0.72	4.79
	Asian / Pacific Islander / Other	1.02	0.63	1.65	1.08	0.67	1.73	1.07	0.64	1.78
	Latino	0.56	0.39	0.78	0.57	0.39	0.82	0.64	0.44	0.94
Poverty (Ref. ≥400% FPL)[g]										
	0 - 199% FPL	1.05	0.76	1.45	0.82	0.58	1.17	0.98	0.69	1.40
	200 - 399% FPL	0.92	0.67	1.27	0.84	0.60	1.16	0.86	0.62	1.19
Sex										
	Female vs. Male	0.99	0.76	1.28	0.96	0.73	1.26	0.94	0.71	1.23
Work Status										
	Employed vs Unemployed				0.52	0.37	0.73			
Delay in Care										
	Yes vs No							0.58	0.43	0.80
Household Smoking										
	No vs Yes							0.54	0.37	0.79

*Model 2 also controlled for insurance status, obesity, heart disease, smoking status, and employment status.

**Model 3 also controlled for urban/rural residency, usual source of care, delay in care, household smoking, dog/cat in home, cockroaches in home, household type, household crowding, diabetes, and walking.

Wheeze Attacks, O_3 and Vulnerability Factors **(Asthma-like Symptoms, Children)**

Associations between ≥2 wheeze attacks and vulnerability factors by pollutant

	O^3 (per 10 ppb)								
	Model 1			Model 2*			Model 3**		
Vulnerability Characteristic	OR	95% C.I.		OR	95% C.I.		OR	95% C.I.	
12-Month Pollutant Average	**1.29**	0.90	1.84	1.28	0.89	1.83	1.27	0.86	1.89
Age (Ref. 6-11 years)									
< 6 years old	0.66	0.35	1.25	0.69	0.37	1.29	0.65	0.34	1.25
Race (Ref. White)									
African American	0.32	0.06	1.69	0.26	0.04	1.60	0.38	0.08	1.81
American Indian / Alaska Native	0.21	0.03	1.54	0.18	0.03	1.16	0.16	0.02	1.53
Asian / Pacific Islander / Other	2.07	0.77	5.57	1.84	0.69	4.91	2.55	0.88	7.41
Latino	0.53	0.25	1.15	0.46	0.20	1.07	0.75	0.34	1.65
Poverty (Ref. ≥400% FPL)									
0 - 199% FPL	**3.44**	1.60	7.38	**3.62**	1.59	8.23	**4.88**	2.05	11.63
200 - 399% FPL	**2.42**	1.06	5.55	**2.40**	1.06	5.47	**2.61**	1.10	6.23
Sex									
Female vs. Male	0.93	0.52	1.69	0.88	0.49	1.59	0.93	0.49	1.75
Household Crowding									
No vs Yes							**2.32**	1.02	5.27

*Model 2 also controlled for household smoking, dog/cat in home, cockroaches in home, and insurance status.

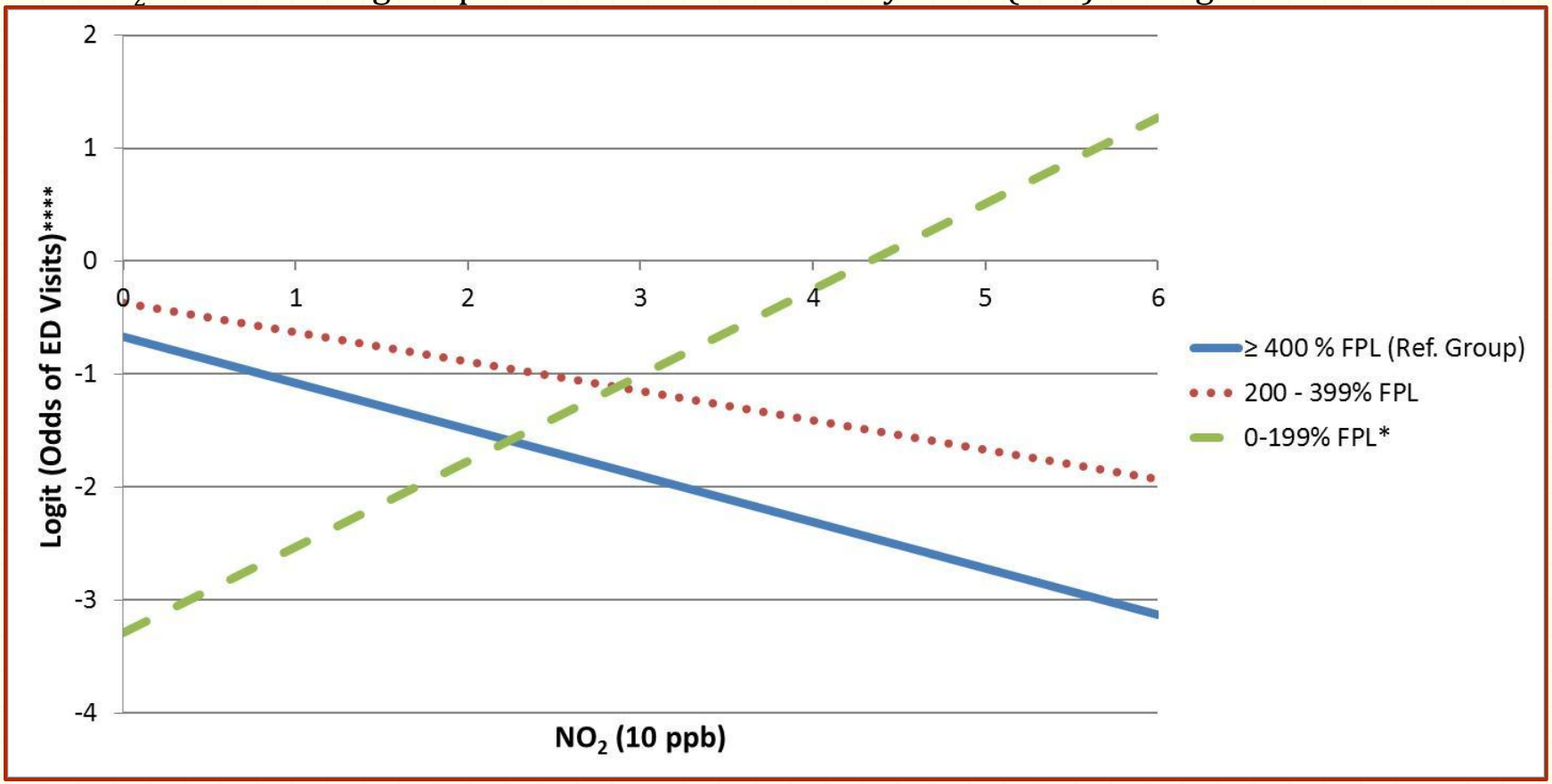
**Model 3 also controlled for urban/rural residency, delay in care, housing type, and household crowding.

Results for Hypothesis #4

Greater pollutant exposure interacts with vulnerability factors resulting in greater air pollution impacts on asthma in vulnerable sub-populations (racial/ethnic minorities, low-income individuals).

Interaction of NO_2 and Poverty on ED Visits **(Current Asthma, Children)**

NO_2 Annual Average Exposure and Federal Poverty Level (FPL) on Log Odds of ED Visits

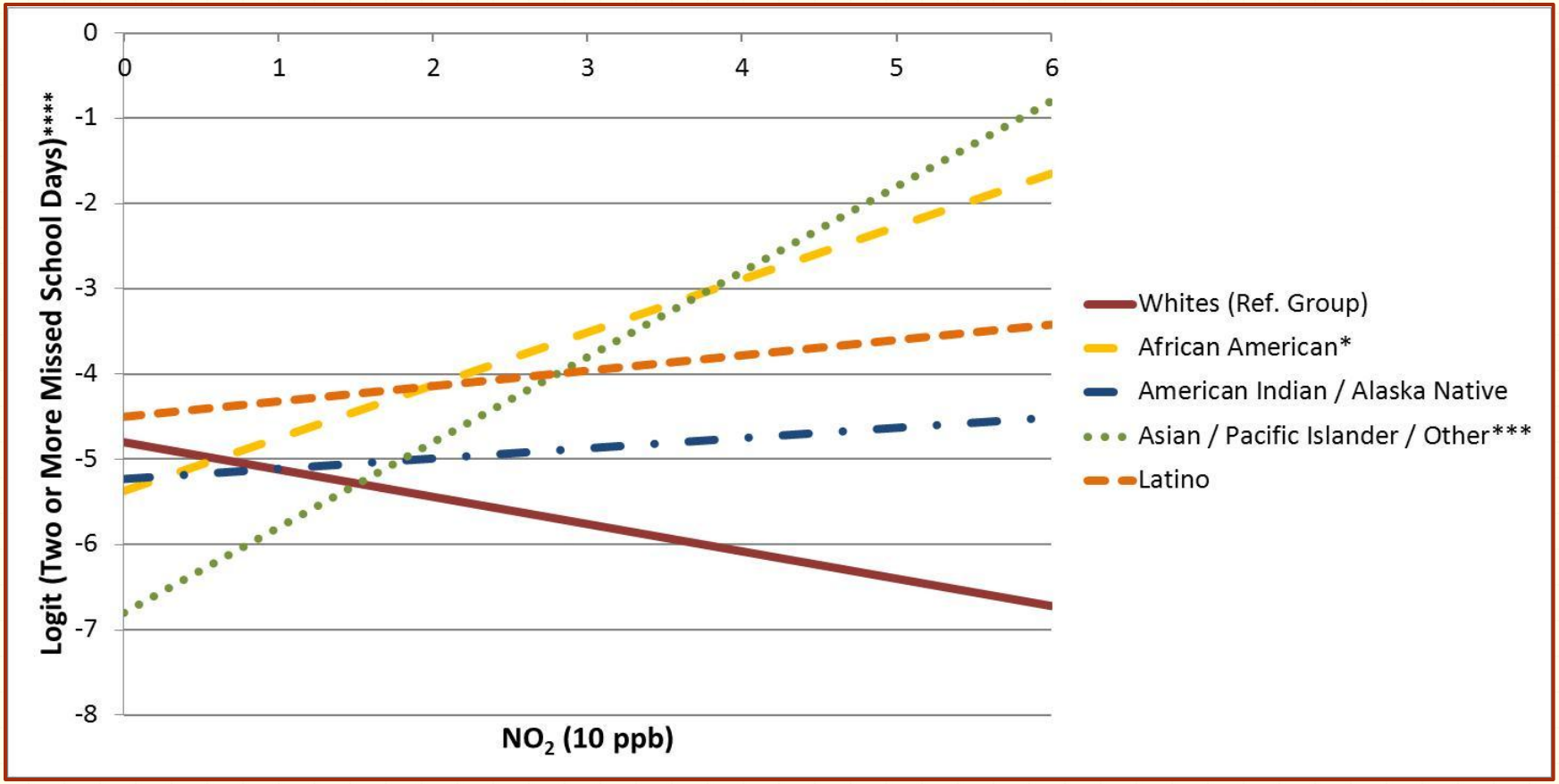


*p < 0.05, **p < 0.01, ***p < 0.001

****Adjusted for age, sex, race and federal poverty level

Interaction of NO_2 and Race on Work Absences **(Current Asthma, Adults)**

NO_2 Annual Average Exposure and Race/Ethnicity on Log Odds of ≥ 2 Asthma-Related Work Absences

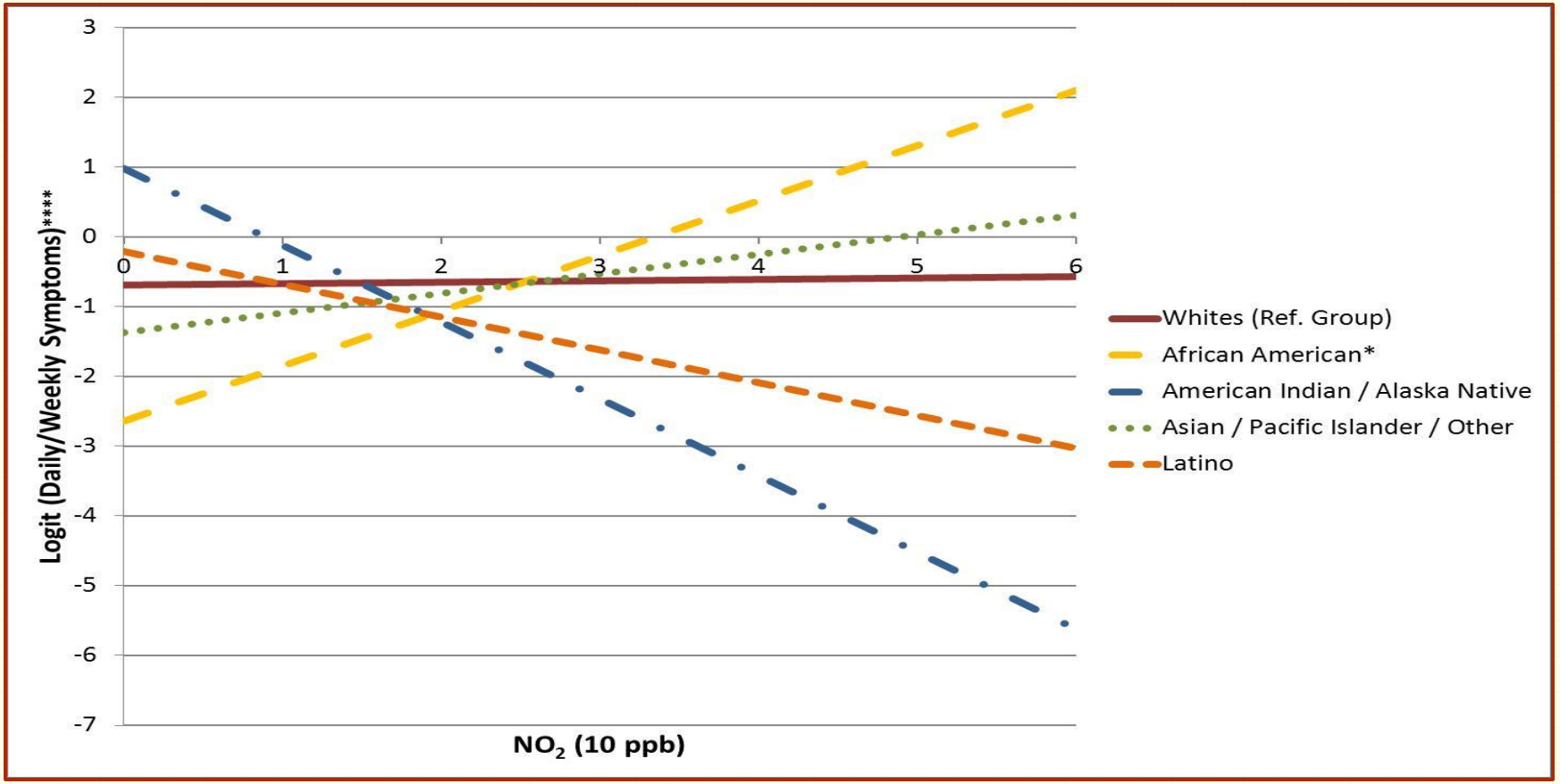


*p < 0.05, **p < 0.01, ***p < 0.001

****Adjusted for age, sex, race and federal poverty level

Interaction of NO_2 and Race on Asthma Symptoms **(Current Asthma, Adults)**

NO_2 Annual Average Exposure and Race/Ethnicity on Log Odds of Daily/Weekly Asthma Symptoms

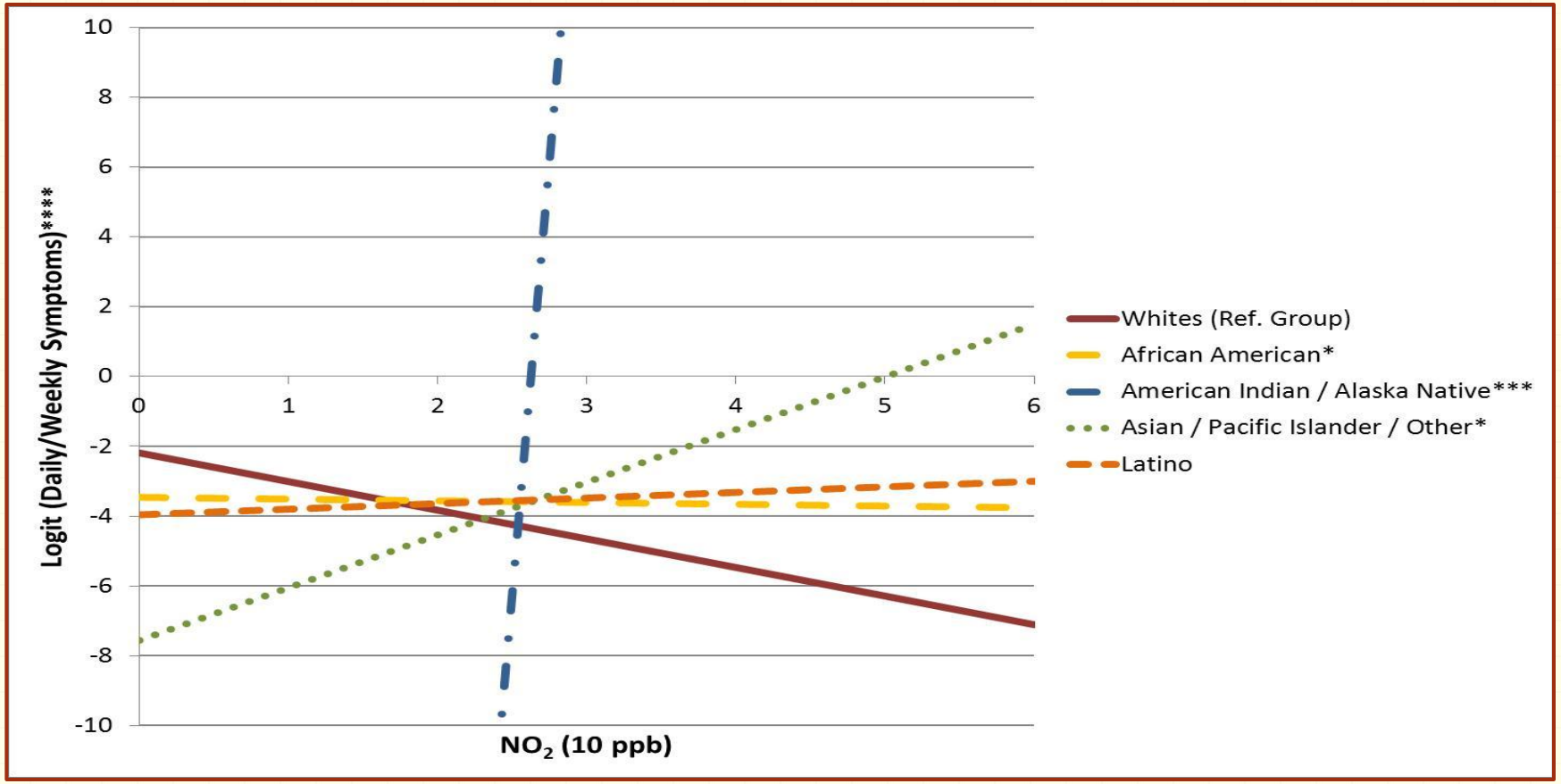


*p < 0.05, **p < 0.01, ***p < 0.001

****Adjusted for age, sex, race and federal poverty level

Interaction of NO_2 and Race on Asthma Symptoms **(Current Asthma, Children)**

NO_2 Annual Average Exposure and Race/Ethnicity on Log Odds of Daily/Weekly Asthma Symptoms

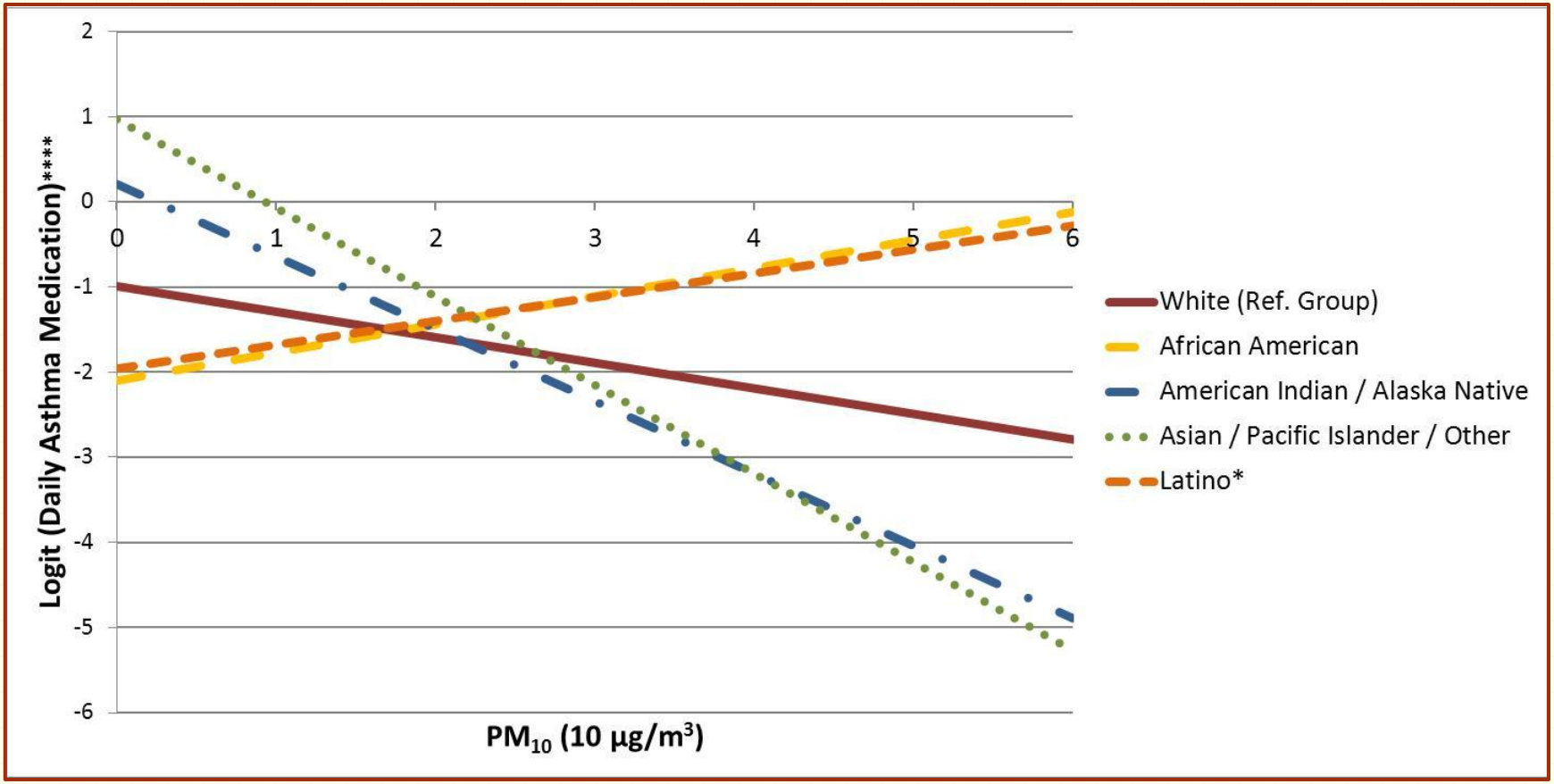


*p < 0.05, **p < 0.01, ***p < 0.001

****Adjusted for age, sex, race and federal poverty level

Interaction of PM_{10} and Race on Asthma Medication Use **(Current Asthma, Children)**

PM_{10} Annual Average Exposure and Race/Ethnicity on Log Odds of Daily Asthma Medication Use

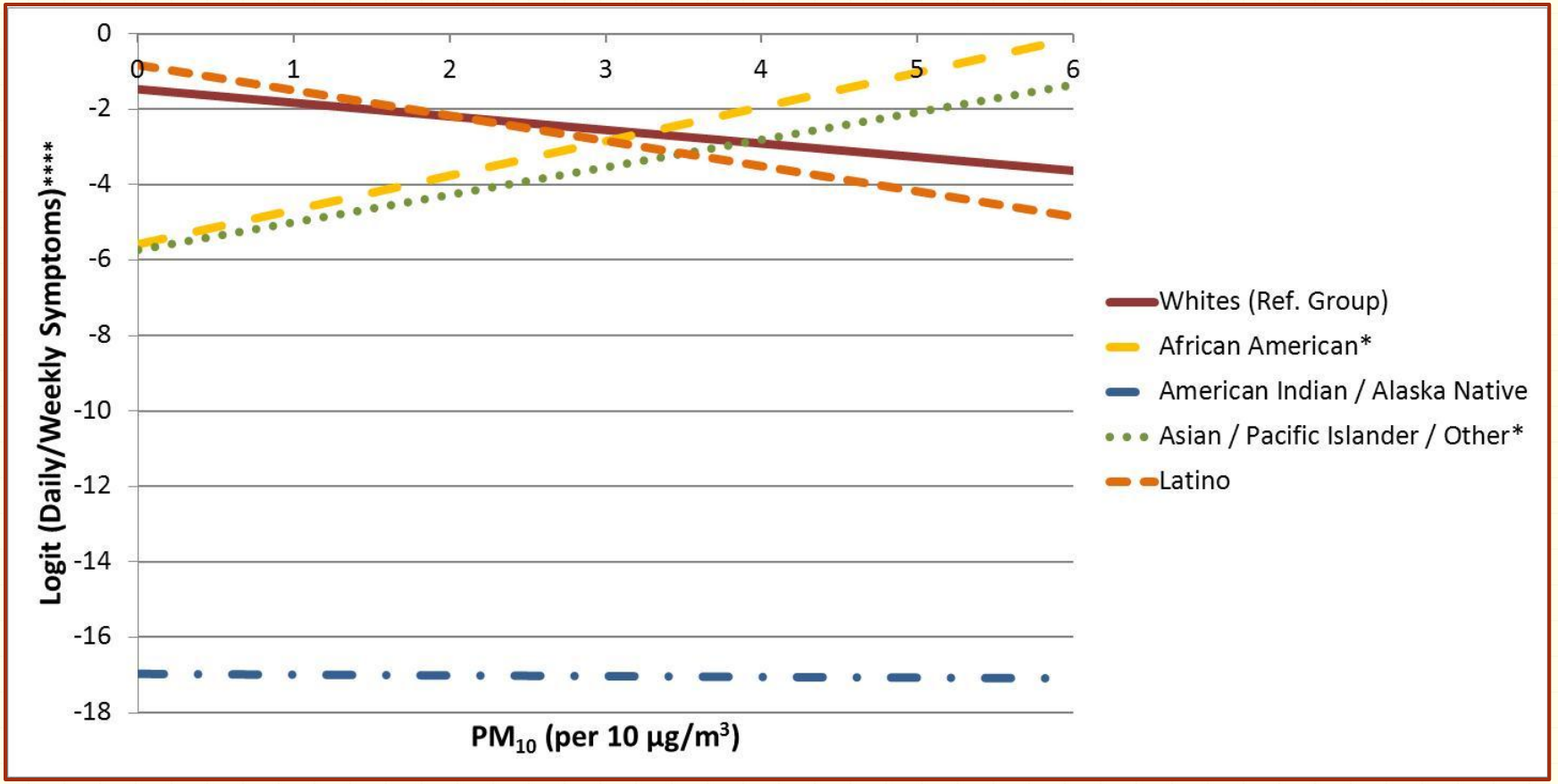


*p < 0.05, **p < 0.01, ***p < 0.001

****Adjusted for age, sex, race and federal poverty level

Interaction of PM_{10} and Race on Asthma Symptoms (**Current Asthma, Children**)

PM_{10} Annual Average Exposure and Race/Ethnicity on Log Odds of Daily/Weekly Symptoms



*p < 0.05, **p < 0.01, ***p < 0.001

****Adjusted for age, sex, race and federal poverty level

Odds Ratios for Interactions of NO_2 and Race or Poverty **(Current Asthma)**

Interaction Effect of 12-month NO_2 pollutant exposure with poverty or race on asthma outcomes

	ED Visits (Children)			Missed ≥ 2 Work Days (Adults)			Daily/Weekly Symptoms (Adults)		
Interaction	OR	95% C.I.		OR	95% C.I.		OR	95% C.I.	
NO_2 (10 ppb) by Household FPL									
0-199% FPL	**2.14**	1.22	3.74						
200-399% FPL	0.77	0.41	1.45						
≥400% FPL†	0.66	0.33	1.34						
NO_2 (10 ppb) by Race									
Latino				1.20	0.72	2.03	0.63	0.38	1.03
American Indian / Alaska Native				1.13	0.23	5.53	0.33	0.07	1.52
Asian / Pacific Islander / Other				**2.72**	1.32	5.61	1.32	0.74	2.38
African American				1.86	0.87	3.96	**2.21**	1.13	4.33
White†				0.73	0.47	1.12	1.02	0.81	1.29

†Reference group

Sensitivity Analysis
(Current Asthma, Adults)

Associations for 12-month pollutant averages and ED Visits stratified by medication use

	Daily Asthma Medication				Overall	
	Yes		No			
Pollutant	Adj. OR*	95% C.I.	Adj. OR*	95% C.I.	Adj. OR*	95% C.I.
O_3 (per 10 ppb)	1.08	[0.83, 1.40]	1.23	[0.84, 1.80]	**1.19**	[0.96, 1.47]
PM_{10} (per 10 µg/m^3)	**1.14**	[0.90, 1.44]	**1.23**	[0.90, 1.68]	**1.20**	[1.00, 1.43]
$PM_{2.5}$ (per 5 µg/m^3)	1.20	[0.88, 1.62]	1.09	[0.71, 1.65]	**1.22**	[0.96, 1.56]

*Adjusted for age, sex, race and federal poverty level

Sensitivity Analysis
(Current Asthma, Adults)

Associations for 12-month pollutant averages and work absences stratified by medication use

	Daily Asthma Medication				Overall	
	Yes		No			
Pollutant	Adj. OR*	95% C.I.	Adj. OR*	95% C.I.	Adj. OR*	95% C.I.
O_3 (per 10 ppb)	1.08	[0.83, 1.40]	1.23	[0.84, 1.80]	**1.19**	[0.96, 1.47]
PM_{10} (per 10 µg/m^3)	**1.14**	[0.90, 1.44]	**1.23**	[0.90, 1.68]	**1.20**	[1.00, 1.43]
$PM_{2.5}$ (per 5 µg/m^3)	1.20	[0.88, 1.62]	1.09	[0.71, 1.65]	**1.22**	[0.96, 1.56]

*Adjusted for age, sex, race and federal poverty level

Summary

- Exposure Disparities (Current Asthma):
  - Higher annual average exposures among lower income groups and racial/ethnic minorities for NO_2, PM_{10}, and $PM_{2.5}$
  - Higher annual average O_3 exposure among those with higher income individuals and whites

- Pollutant-Outcome Associations (Current Asthma):
  - Adults -- Increased O_3, PM_{10}, and $PM_{2.5}$ associated with increases in all asthma outcomes
  - Children -- Increased NO_2 associated with increased odds of daily asthma medication use and school/day care absences

- Vulnerabilities (Current Asthma, adults):
  - Pollutant associations for O_3, PM_{10}, and $PM_{2.5}$ remained after adjusting for potential confounders.
  - Being African American or Latino, living below 200% of the FPL, being a smoker, having heart disease and having adult onset asthma were related to increased odds of adverse asthma outcomes.

Summary

- Interactions (Current Asthma):
  - Adults -- observed between race/ethnicity (African American and Asian/PI/other) and annual average pollutant exposures for NO_2
  - Children --
    - observed between race/ethnicity (American Indian/Alaska Native and Asian/PI/other) and annual average pollutant exposures for NO_2
    - observed between race/ethnicity (Latino, African American, and Asian/PI/other) and annual average pollutant exposures for PM_{10}
    - observed between household FPL (>200%) and annual average pollutant exposures for NO_2
  - **Findings suggest racial/ethnic minority and low-income groups have greater increases in adverse health effects at the same level of increase in exposures.**

Limitations

- One-year, cross-sectional data from a sample of Californians
- Self-reported, rather than clinical outcomes
- Selection bias due to non-response
- Respondent recall bias
- Non-coverage bias due to exclusion of cell-phone-only population
- Residence-based air pollution exposure estimates only
- Individual exposure differences due to time spent outdoors, housing type and indoor pollution exposures

Recommendations

Vulnerable populations need greater protection against air pollution exposure.

- Identify contributing sources and toxic constituents of air pollution
  - Need additional monitoring of air pollution from mobile sources (e.g., near freeways and major roads)
- Intervene at the community level through statewide guidance
  - For example, recommend minimum distances to pollutant sources (e.g. busy roadways) for schools, day care centers, work places, homes, sports fields and parks
- Intervene at the individual level through education on how to control air pollution exposures
  - Reduce outdoor activities when air quality index is unhealthy range
  - Exercise away from major roadways

Recommendations

Further study is needed in the following areas:

- Relationships between socioeconomic status and race with air pollution and respiratory health effects
- Factors that may increase or mitigate pollutant effects
- Community-based or family-focused interventions to reduce individual exposures and vulnerability to air pollution

On behalf of the research team and UCLA CHPR

Thank you!

For further distributions or questions/comments, please contact:

Ying-Ying Meng, DrPH
(310)-794-2931
yymeng@ucla.edu

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